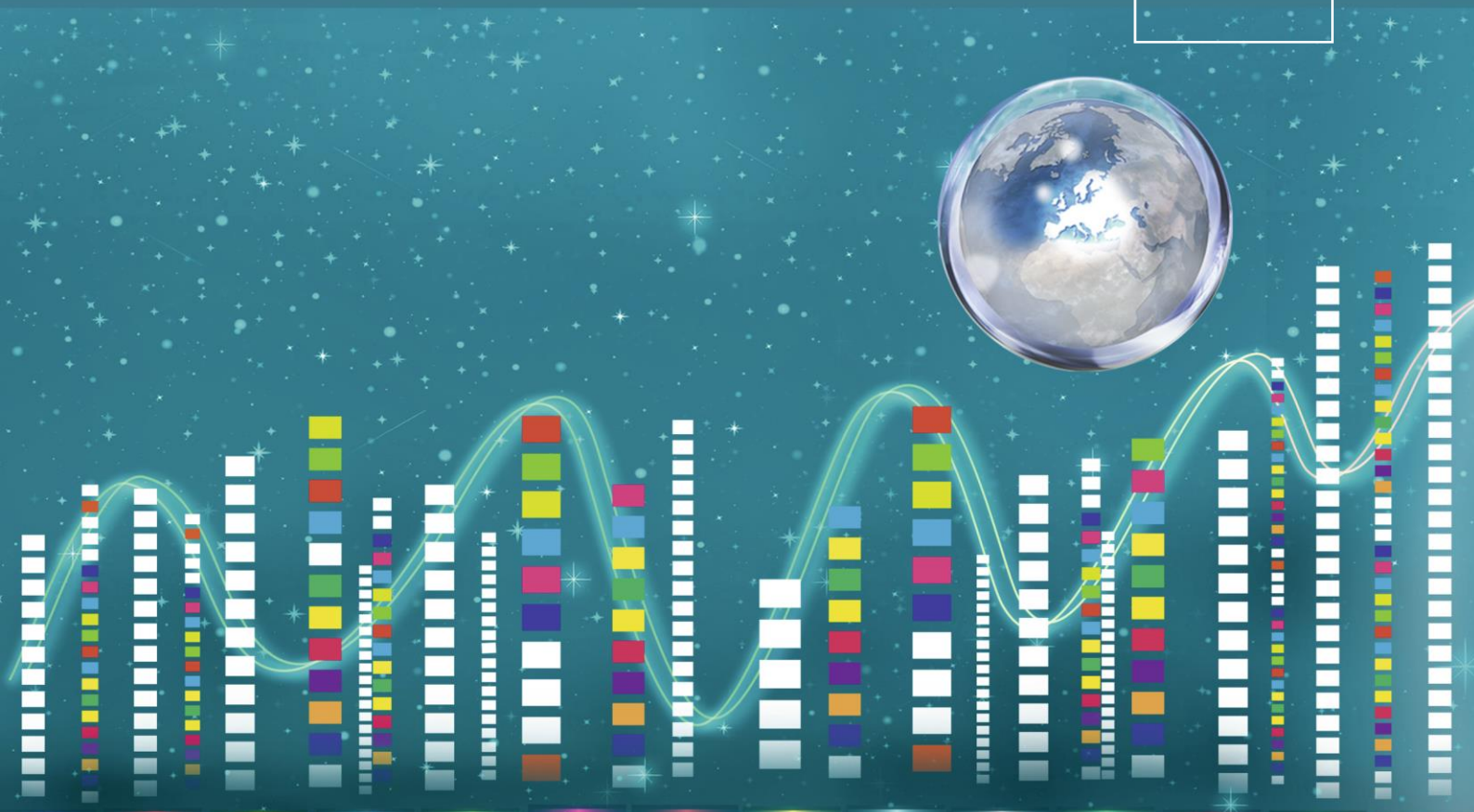
European Commission

Evaluation Study on the European Framework Programmes for Research and Innovation for Addressing Global Challenges and Industrial Competitiveness – Focus on Activities for the Digital and Industrial Transition

Phase 1 Final report – Horizon 2020

Independent Expert Report



Research and Innovation

Evaluation Study on the European Framework Programmes for Research and Innovation for Addressing Global Challenges and Industrial Competitiveness – Focus on Activities for the Digital and Industrial Transition – Phase 1 Final report – Horizon 2020

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Evaluation Study on the European Framework Programmes for Research and Innovation for Addressing Global Challenges and Industrial Competitiveness – Focus on Activities for the Digital and Industrial Transition

Phase 1 Final report – Horizon 2020

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

AC	Associated countries
AI	Artificial Intelligence
CORDA	Common Research Data Warehouse

CSA	Coordination Support Action
CSC	Common Support Centre
DG	Directorate General
DIT	Digital & Industrial Transitions
EBIT	Earnings Before Interests and Taxes
EC	European Commission
ECSEL	Electronic Components and Systems for European Leadership
EDA	European Defence Agency
EDIH	European Digital Innovation Hubs
EGNOS	European Geostationary Navigation Overlay Service
EGNSS	European Global Navigation Satellite System
EIP	European Innovation Partnership
EIT	European Institute of Innovation & Technology
EMPIR	European Metrology Programme for Innovation and Research
ERA	European Research Area
ERC	European Research Council
ESA	European Space Agency
ESIR	Expert group on the economic and societal impact of research and innovation
ETP	European Technology Platform
EU	European Union
EUSPA	European Union Agency for the Space Programme
FET	Future and Emerging Technologies
FOAK	First of a Kind
FoF	Factories of the Future
FP	Framework Programme
FSTP	Financial Support to Third Party
H2020	Horizon 2020
HES	Higher or Secondary Education Organisation
HEU	Horizon Europe
HLG	High-level expert group
HPC	High-Performance Computing

IA	Innovation Actions
ICT	Information & Communication Technologies
IPR	Intellectual Property Rights
JRC	Joint Research Centre
JU	Joint Undertaking
KDT	Key Digital Technologies
KET	Key Enabling Technologies
KIC	Knowledge & Innovation Community
LE	Large Entreprises
LEIT	Leadership in Enabling and Industrial Technologies
MS	Member States
NACE	Statistical classification of economic activities in the European Community
NCP	National Contact Point
NGI	Next Generation Internet
NGO	Non-Governmental Organisation
NMBP	Nanotechnologies, Advanced Materials, Biotechnology and Advanced Manufacturing and Processing
OEM	Original Equipment Manufacturer
OITB	Open Innovation Test Bed
P2P	Public to Public Partnership
PASTSAT	EPO Worldwide Patent Statitistical Database
PPP	Public Private Partnership
PRS	Public Regulated Services
REC	Research Organisation
RIA	Research & Innovation Actions
RMS	Research Management Services
RRI	Responsible Research and Innovation
RTD	Directorate General for Research and Innovation
RTO	Research and Technology Organisation
SDG	Sustainable Development Goals
SIO	Strategic Innovation Programme (SE)

SME	Small and medium-sized entreprises
SNA	Social Network Analysis
SPIRE	Sustainable Process Industry through Resource and Energy Efficiency
SRIA	Strategic Research and Innovation Agenda
SSH	Social Sciences and Humanities
S&T	Science and Technology
STI	Science Technology and Innovation
TFEU	Treaty of the Functioning of the European Union
TRL	Technology Readiness Level
UN	United Nations
US	United States
WG	Working Group
WP	Work Programme

ABSTRACT

The purpose of the first phase in the 'Evaluation Study on the European Framework Programmes (FP) for Research and Innovation for Addressing Global Challenges and Industrial Competitiveness – Focus on Activities for the Digital and Industrial Transition' is to evaluate the contribution of the Horizon 2020 (H2020) Framework Programme to the Digital and Industrial Transition. This work supports the European Commission's ex-post evaluation of H2020. The evaluation considered all activities under the H2020 Pillars and Priorities. At the core was the H2020 'European leadership in enabling and industrial technologies' (LEIT) programme under the Industrial Leadership Priority. The scope included the LEIT-related public-private and public-to-public partnerships and EIT KICs. The evaluation was conducted between January and November 2022, using a mix of quantitative and qualitative methods.

The findings overall show that H2020 made a noteworthy contribution to the Digital and Industrial Transition by responding to the changing landscape developments and supporting breakthrough innovations, bringing them closer to maturity and, thus, lowering the risk of industrial investments in key enabling technologies. The high attention for the creation and strengthening of knowledge ecosystems, the development of infrastructures and pilot lines, and the improvement of framework conditions were critical from that perspective. The increased input from industry actors and technological experts in the programming process ensured a stronger alignment with the needs of the targeted industry sectors and end-users, setting the conditions towards genuine transformation. Throughout H2020, a key area of improvement was the greater policy coordination with Member States observed in the later stages of the Framework Programme and under continuing H2020's successor, Horizon Europe. Another observation was that the LEIT programme's effectiveness could be underestimated due to lack of data. There is also a clear need for the FP Monitoring and Evaluation System to be enhanced in order to better assess the FP's performance in the context of a transformative R&I policy.

EXECUTIVE SUMMARY

This final report provides the results of the 'Evaluation Study on the European Framework Programmes for Research and Innovation for Addressing Global Challenges and Industrial Competitiveness – Focus on Activities for the Digital and Industrial Transition', commissioned by DG Research and innovation (DG RTD). The evaluation was implemented in the period January 2022 to November 2022 by a consortium consisting of Technopolis Group, AIT, Fraunhofer ISI, and Science-Metrix.

The evaluation considered all activities under the three H2020 pillars that contributed to the **Digital and Industrial Transition** (DIT). At the core was the H2020 programme part European Leadership in Enabling Industrial Technologies' (LEIT) under the Priority "Industrial Leadership". The evaluation also covered the LEIT-relevant 'horizontal' and 'vertical' public-private partnerships (PPP) and public-to-public partnerships (P2P), as well as the EIT Knowledge and Innovation Communities (EIT KICs). The key findings reported below are based on a broad mix of qualitative and quantitative data collection and analysis methods, including among others, case studies, bibliometrics, and intellectual property rights (IPR) data analyses.

The summary of the key findings follows the structure of the report. The conclusions and recommendations are detailed in the final chapter to this report.

Context and state of play

The Europe 2020 strategy for a smart, sustainable, and inclusive growth (including the Digital Single Market strategy)[1], the Juncker Commission Ten Priorities[2], the European Key Enabling Technologies (KETs) strategy[3], and the policy developments leading to the definition of the EU industrial strategy and EU Space Strategy all set the policy context for the H2020 contributions to DIT. The objective of the H2020 LEIT programme part was: "To maintain and build global leadership through research and

[1] EC (2010) Europe 2020. A Europen strategy for smart, sustainable and inclusive growth, COM(2010) 2020.

[2] A New Start for Europe: My Agenda for Jobs, Growth, Fairness and Democratic Change – Political Guidelines for the next European Commission, Opening Statement in the European Parliament Plenary Session, Jean-Claude Juncker, Candidate for President of the European Commission, Strasbourg, 15 July 2014.

[3] EC (2012) A European strategy for Key Enabling Technologies – A bridge to growth and jobs, Communication from the Commission COM(2012) 341 final.

innovation in enabling technologies and space, which underpin competitiveness across a range of existing and emerging industries and sectors."

Our estimation is that H2020 funded 6,484 projects contributing to the Digital and Industrial Transition (DIT), accounting for an EU contribution of €24.8bn or 32% of the total H2020 budget. Slightly more than half of the DIT funding (55%) was dedicated to research in the Industrial Leadership Pillar II (mainly in the LEIT programme part), about 30% in the Societal Challenges Pillar III, and about 15% under the Excellent Science research Pillar I.

The **LEIT programme part** was at the core of the H2020 contributions to DIT. It funded 3,161 projects with an EU contribution of €10.3bn. The LEIT ICT programme accounted for about 55% of the budget (€5.8bn), LEIT NMBP for about 35% (€3.5bn), and LEIT Space for about 10% (€0.98bn) [4].

Relevance

Based on desk research and interviews, the objectives of the LEIT programmes, as they were translated into the focus of the calls and the use of action types and funding instruments, were highly relevant to overcome the scientific and technological (S&T) challenges and long-standing structural weaknesses that hinder the EU's global competitive positioning, while tackling the societal challenges that Europe and the world faced.

Acting upon the emerging **S&T and socio-economic needs**, the LEIT programmes supported technological developments that set the basis for innovation across multiple sectors in a wide variety of processes, goods, and services. The research focus was on cost reductions and faster production lines, innovative applications in downstream user sectors, and safeguarding space infrastructure, among others. Research activities aimed at supporting EU industry in its 'societal mission' of adopting sustainable, environment-friendly products and services, enhancing energy and resource efficiency, human-centred production processes, 'safe-by-design' or 'ethics-by-design' products and services, and ensuring trustworthy connectivity. Research was funded also to mitigate the adverse effects of technological innovations such as the energy consumption of microelectronics and advanced computing, and e-waste. The flexibility and responsiveness to changing needs and developments was apparent in the shift in focus over time from a challenge-based perspective in the first half of H2020, with industrial competitiveness and job growth as main targets, to an impact-based perspective reflecting the broader EU priorities.

The LEIT programmes acted upon major barriers that negatively influence the absorption of technological innovation in EU industry, such as the level of university-industry collaboration, the ongoing innovation divide in Europe, and most important, the relatively low industry investment in R&D. Broadly, the stakeholders who were consulted confirmed the alignment of the directions set in the LEIT programmes with the **stakeholder needs**. They indicated a good alignment between their drivers for participation and the LEIT programmes activities.

Efficiency

To enhance the efficiency of its **administration and management processes**, the EC increasingly adopted new management modes such as the delegation of programme management to Executive Agencies or other entities (e.g. by means of Specific Grant Agreements) under H2020. There was also a considerable – and over time increasing – use of the cascade funding model (or Financial Support to Third Parties, FSTP) under the LEIT programme part throughout the FP, in multiple types of actions and instruments.[5] Overall, the stakeholders consulted gave positive feedback on the H2020 simplification measures. Most valued was the significant improvement of the time-to-grant (TTG) compared to the predecessor programme, FP7. Survey respondents saw room for improvement in the worktime recording and the personnel costs calculation rules. Transparency of the funding decisions and completeness of the evaluation reports are lasting issues.

[4] The field of Industrial Biotechnology and the EEB cPPP are not included in the LEIT-NMBP figures, as these have been covered in the H2020 Evaluation Study on Green Transition; these figures also exclude Joint Undertakings, including BBI (covered by the Green Transition study).

[5] The non-availability of data on EC costs at the detailed FP programme part level (related to difficulties in distinguishing between programme- and policy-related activities of EC officials) as well as centralised data on the FSTP inhibited an assessment of the EC efficiency in programme implementation from this perspective.

The **funding distribution**[6] over the action types showed a focus on Research and Innovation Actions (RIA) (about 50% of the LEIT budget), followed by the Innovation Actions (IA) (about 40%). Coordination and Support Actions (CSA) and the SME Instrument accounted for 4% of the budget, each. The trend over time showed a gradual decrease in the funding of RIAs[7] and an increase in the funding share of IAs. This trend specifically regarded the LEIT ICT and especially the NMBP programme. In terms of funding instruments[8]**,** the LEIT programme part allocated around 10% of its budget to technology infrastructures – evolving from 5% in 2014-2015 to close to 20% in 2018-2020. This trend was accompanied by a steady decrease in the funding of the 'standard' collaborative RIA projects (from 60% in 2014-2015 to 50% in 2018-2020), and the discontinuation of the SME Instrument funding under LEIT.[9] The funding of large-scale technology infrastructures in the LEIT ICT and NMBP programmes, together with the drive towards involving multiple value chains in a single project, led to relatively high average project budgets and sizes, for all types of instruments (and higher than under FP7).

The LEIT programme part had an **overall success rate of 9%** (eligible proposals). Taking account of the influence of the (new) SME Instrument, which had a particularly low success rate (6%), LEIT reached a 'comparative' success rate of 15% – only slightly lower than FP7's 17% for the equivalent programmes.

The LEIT programme part funded **27,474 'participations'** by **11,323 unique stakeholder organisations**, including 6,763 newcomer organisations[10], which accounted for about 35% of all participation and about 25% of the funding. **Research Organisations** were the main beneficiaries, making up about 30% of the funding, closely followed by the three other main stakeholder groups (**Higher Education Institution**s, **SMEs**, and **Large Enterprises**) with about 20% of the funding each. The H2020 target of minimal 20% of the funding allocated to SMEs was over-reached in all LEIT programmes.

The stakeholders showed different **participation patterns** in the funding instruments.[11] Seeing the change in funding priority for these instruments over time, it implied a corresponding change in the LEIT stakeholder funding – specifically, an increase in the funding share for the Research Organisations and a decrease in the funding of Higher Education Institutions and SMEs.[12] It should be noted, however, that the effects of the cascade-funding model are not accounted for. This implies that, for example, funding data for Research Organisations risks being over-estimated since the budget for third-party funding is officially allocated to the project partner responsible; data on the funding of SMEs, which were the main intended beneficiaries of the FSTP model, risk being under-estimated.

From a **geographical** perspective, the funding was concentrated on the former EU15 Member States (accounting for close to 90%). The EU13 MS and the H2020 Associated Countries each accounted for around 7% of the funding; Luxembourg, Greece, and Cyprus showing the highest participation intensity.[13] Involvement of Third Countries was very limited (506 'participations' or 2% of the total), with about half of them by organisations in high-income countries.

Survey respondents overall appreciated the EC **project management** approach in terms of reporting requirements, the user-friendliness of the project management and monitoring tools, and the EC's flexibility in adapting the projects to changes in the environment and/or project consortium. They, however, emphasised the considerable efforts needed for the management of increasingly complex projects. To overcome human resources constraints and reduce risks, project coordinators increasingly turned to specialised private entities to take charge of administrative and financial project management tasks. Project coordinators indicated the positive effects of this approach since it allowed them to focus

[6] The analysis of efficiency in funding distribution focused on the LEIT programme part only.

[7] For the RIAs the funding shares evolved from 60% of the LEIT budget in 2014-2015 to 50% in 2018-2020; for the IAs the trend was from 30% in 2014-2015 to about 50% in 2018-2020.

[8] H2020 Framework Programme introduced a set of 'demand-side innovation' funding instruments, including the (bottom-up innovation) SME Instrument and public procurement measures, and under the LEIT ICT and NMBP programmes, instruments that aimed at enabling access to technology infrastructures (platforms, hubs, pilot lines, and testbeds).

[9] The SME Instrument was funded under the EIC Pilot in 2018-2020 (Accelerator scheme).

[10] Organisations that had not participated under FP7.

[11] Research Organisations were the main beneficiaries in all instruments except for the 'standard' collaborative research RIA, but especially so in the platforms/hubs and testbeds where they accounted for about 40% of the funding. Higher Education institutions, instead, were the main beneficiaries of the 'standard' collaborative research RIA and accounted for (only) 17% of the funding for the testbeds.

[12] The funding shares of the SMEs were (quite obviously) influenced by the discontinuation of the SME Instrument funding under the LEIT programmes. In addition, however, also their limited budget shares in the platforms/hubs (compared to the 'standard' RIA and IA) played a role.

[13] Defined as EU contribution in relation to the population of scientists and engineers.

on what, in their opinion, matters most for project success, i.e. the scientific coordination. They criticised the EC definition of the project coordinator's role and the related budgeting rules for not making an adequate distinction between administrative and scientific coordination tasks.

The **FP monitoring system** presented specific strengths on monitoring the progress of the Framework Programme from an operational perspective, it however showed limited capacity for a more fine-grained assessment of knowledge and innovation dynamics from a transformative R&I policy perspective, and the longer-term spillovers in EU industry at large.

Among the services provided by the EC to facilitate the **valorisation of research results**, stakeholders appreciated and attributed a high level of importance to the EC dissemination activities and platforms as well as the EC communication activities to stakeholder groups. Opinions were more divided on the importance of platforms and measures such as the IPR helpdesks, digital marketplaces, and IP boosters.

In terms of **cost-effectiveness**, the LEIT programme part had a direct leverage effect of industry contributions amounting at €3.93bn, thanks to the private-sector contributions to the project costs.

Effectiveness

There are important limits to the assessment of H2020's effectiveness in this evaluation since it was conducted at a time when LEIT projects, which had concluded their activities, accounted for (only) 53% of the funding. Bearing in mind the minimal timeframe of two years from a project's end for tangible effects to materialise, the timing of the evaluation implied that measurable results were available for 50% of the projects in the LEIT programme part, representing only 30% of the LEIT funding.

Achievement of the objectives

In terms of **scientific outcomes,** the clearest effects of H2020 support for the DIT was in terms of enabling open access publishing and fostering research-industry co-publications. On these two dimensions, H2020 enabled researchers to achieve higher performances than under FP7 and in their other publications not funded by H2020. Research funded under the DIT area and the LEIT programmes also generally stood out in terms of international co-publications. In terms of cross-disciplinarity, overall H2020 DIT research performed at (or slightly above) world level, but not differently from FP7 and non-FP funded research when it came to its share of highly multidisciplinary and interdisciplinary journal publications. H2020 and LEIT research in the field of space technologies performed best from this perspective, research in the LEIT ICT showed the lowest level of cross-disciplinarity.

Scientific excellence (defined as citation impact profiles) was one of the areas in which H2020-funded research recorded its strongest and clearest achievements. For the H2020 contributions to DIT overall, as well as the three LEIT programmes, analyses show higher citation distribution indices (CDIs) and greater shares of highly cited publications than for (non-FP funded) research in the EU and international comparators. Here, special mentioned should be made of the high CDI scores recorded for DIT-related publications in the European Research Council (ERC), Marie Skłodowska-Curie Actions (MSCA), and Future and Emerging Technologies (FET) programmes, very much above the EU average.

The rather low activity in the **valorisation** of the research results is a cause of concern. Despite the stronger innovation orientation of H2020 compared to FP7, the IPR production (based on self-declared outputs) was at similar levels as under FP7 – both in terms of average number of IPR applications per project (0.2 IPR applications per project in both FPs) and per €10m funding (0.6 IPR applications per €10m under LEIT versus 0.5 under FP7). Photonics was the Key Enabling Technology (KET) to which LEIT projects contributed most (61 patents or 40% of the total), followed by Micro/Nanoelectronics (47 or 30%), and Industrial Biotechnology (31 or around 20%). Innovation Radar data show a high number of innovations with a rather low maturity level, i.e. they were still in their early stages and just emerging or the market did not exist. Exceptions in ICT were innovations generated in the horizontal programme as well as Internet of Things and Advanced Computing, where some innovations were in their market-creating stage. The same held for Emerging Enabling Technologies and Advanced Materials in the NMBP area and the cross-cutting Space Innovation programme, which on average produced the most market-ready innovations.

The LEIT programmes might have already had a positive effect on the participating firms' **economic performance**. Based on ORBIS data, private-sector participants had a higher labour productivity and

especially, a higher profitability than comparable non-FP participants. Structural economic effects[14] in the EU can be expected especially in the manufacturing, information and communication, energy supply, and transport and storage sectors. Crunchbase data showed that 11% of SMEs participating in the LEIT programmes succeeded in raising post-project private funding for a total of €9.4bn, mainly through venture capital and other equity funding. Most of the private funding (70%) was raised by SMEs active in high-value-added service industries (computer programming, R&D, and engineering). Several manufacturing sectors raised high shares of funding compared to their size in the LEIT SME population: among others, manufacture of electrical equipment and computers, pharmaceutics, and motor vehicles. Taking into account their share in the LEIT population, the SME Instrument was the action type that was most inducive for participating SMEs to achieve post-project private funding, followed by the Research and Innovation Actions.

The H2020 DIT and LEIT programmes' publications showed a strong performance in receiving **policy-related citations**.[15] At the H2020 DIT level, publications saw nearly three times more policy-related uptake than the EU (non-FP) baseline and nearly twice as much as the FP7 publications. At the level of LEIT programmes, especially LEIT NMBP publications and LEIT Space publications received greater interest in the policymaking process than FP7 baseline publications and the world level.

The H2020 DIT and LEIT programmes awarded funding to researchers with a strong propensity (above EU average) to publish research thematically aligned with the sustainable development and climate **EU policy priorities**. Overall, about 20% of DIT publications contributed to the green transition agenda, driven by DIT publications in the Industrial Technologies area and LEIT NMBP and LEIT Space publications. Compared to the (non-FP funded) EU28 average, a greater proportion of research funded under the LEIT ICT programme was thematically aligned with the policy priorities of a human-centric technological development and industry, and a safe, secure and geopolitically resilient society. In terms of the **UN Sustainable Development Goals** (SDG), the publications contributed mainly to SDG9 'Industry, innovation, and infrastructure', SDG7 'Clean and Affordable Energy', and SDG11 'Sustainable Cities and Communities'. Innovation outputs mainly addressed SDG7 'Clean and Affordable Energy', SDG8 'Decent Work and Economic Growth', and SDG12 'Responsible Consumption and Production'.

Overall, **online dissemination and outreach** efforts can be considered to have been successful. Compared to the (non-FP funded) EU average, H2020 DIT and LEIT publications received more than double the share of 'altmetric' mentions in news outlets and mentions on Wikipedia. These results were mainly due to strong overall networking capacities of the funded researchers, but also sometimes because the funding allowed researchers to improve their performance in these dimensions. These results can be put in context to the very strong performance of Open Access publications helping to make scientific results accessible to society.

Partnerships for which data on publications could be assessed[16] recorded positive impacts in terms of open access, academic-private co-publication, and citation impact. For the dimensions of international co-publication and cross-disciplinarity, however, their performance was weaker than non-FP funded EU research. In terms of innovation outputs, the relative patent output of the partnerships was higher than that of the mainstream FP projects. This held especially for the Joint Undertakings (JU), where 13% of the projects filed at least one patent, compared to about 6% in the cPPP-based projects and 5% of the mainstream FP ones. For almost all partnerships, the thematic alignment of their publications with the SDGs was on par or even below the EU average. An exception was the cPPP FoF, which recorded a share of SDG-aligned publications more than twice the EU average. Alignment with the Green Deal objectives varied greatly, but was at best on par with the researchers' other publications or the EU average.

Enabling factors and barriers

Stakeholders consulted confirmed that the **strong systemic approach** taken in the LEIT programmes, with an explicit focus on supporting innovation and facilitating the creation of 'knowledge value communities' and cross-sectoral knowledge ecosystems, was overall in line with the **needs of R&I**

[14] Economic effects on the participating companies combined with an estimate of their (aggregated) market share in their sector (in Europe).

[15] Journal publications may contain findings or evidence of interest in the policymaking process understood broadly (ranging from syntheses of evidence prepared by scientists for a policymaking public, to parliamentary and regulatory work on policy change). New databases make it possible to track instances where journal publications have been cited in policy-related documents.

[16] Partnerships for which enough publications were available for bibliometric assessment were the JU ECSEL, the EIT KICs Digital and Raw Materials, and the cPPPs 5G, Big Data, Cyber-security, FoF, Robotics, and SPIRE.

communities. The participation patterns of the industry actors show that thanks to this alignment, the LEIT programmes succeeded in attracting SMEs and Large Enterprises active in different sectors and, most importantly, fostered their participation across programmes and intervention areas. Overall, the Artificial Intelligence, Manufacturing and Processing Technologies, and Advanced Materials intervention areas stood out for their higher-than-average level of intersectoral research.

The trend towards the funding of research projects involving actors **across value chains** and the creation of **technology infrastructures** was broadly appreciated by the stakeholders. The resulting funding concentration on fewer, high-cost projects, however, raised various concerns, including the creation of 'winner takes all' dynamics, and in the case of the technology infrastructures, an enhanced tension between the excellence and cohesion policy objectives. In addition, the longer-term sustainability of these technology infrastructures appears uncertain – unless they are part of a broader long-term agreement between the EC and MS, such as those set up for the European Digital Innovation Hubs (EDIH or DIH) and the cyber-security competence centres.

The LEIT programmes appear *not* to have been in line with stakeholder needs in their focus and allocation of funding for the conduct of pre-standardisation research and international collaborations. Case studies highlighted the need for improved integration of standardisation activities in the programme portfolio and the importance of international cooperation in this context, next to the value of strengthening the knowledge base of EU companies and Research Organisations. The highly limited participation of Third Countries in the LEIT programmes, and especially actors located in high-income countries, was a point of concern. Only 6% of the projects in the LEIT programme part – and on average about 3% of the cPPP-based projects – included at least one Third Country participant. Exceptions among the PPPs were the cPPP 5G (12% of the projects) and the JU ECSEL (10%). Delays in the EC negotiations with Third Countries for co-funding agreements as well as a lack of interest among industry participants appeared to have played a role.

The choice of the policy instruments is an important step in the **programme design** process. Interviewees and case studies highlighted the critical importance of a strategic use of the action types and funding instruments, taking their function in the overall policy mix into account and aligned with the maturity of the technologies and the needs in the targeted industry sectors. Several case studies emphasised the need for holistic portfolio management, for example by using a cluster approach based on a clear vision of the projects' purpose in the overall project portfolio or through institutional cooperation steering the project directions. Interviewees also highlighted the important role of the CSA instruments especially in relation to the non-technological aspects of innovation and cross-cutting issues.

Closely related to these concepts was the concern among the research communities that in the field of enabling technologies, the balance in the FP funding between close-to-industry R&D and more fundamental research might get lost. Considering the ongoing decrease in the funding of 'standard' RIA projects, stakeholders highlighted the importance of research with low or mid-level technological readiness for capacity-building in view of longer-term needs ("re-filling the innovation pipeline") and the risk of an increasing decoupling of these two strands of research in the Framework Programme.

Survey respondents attributed a high importance to the EC dissemination activities and platforms as well as the EC communication activities to stakeholder groups to facilitate the take-up of innovation. Interviewees considered that dissemination activities should cover topics beyond the project results, such as favourable business models, holistic sustainable analyses, and non-technical barriers. A more professional – and possibly more centralised – approach to the projects' dissemination activities appears desirable in this context.

Another notable trend was the increasing influence of the cPPP SRIAs on the funding decisions in the LEIT ICT and NMBP programmes. In the LEIT ICT programme, the cPPP SRIAs steered half of the funding, showing an increase over time (from 22% in 2014-15 to 66% in 2018-20) and creating a shift in the balance between cPPP-based and 'mainstream FP' funding. In the NMBP programme, cPPP-based projects accounted for about 40% of the total funding, encompassing close to 100% of the projects in the advanced manufacturing and processing technologies area. The partnerships have shown their effectiveness in aggregating communities and fostering industry investment in research and innovation, creating focus and impact. Nevertheless, the strong reliance on the partnerships' SRIAs raised concerns in relation to the directionality of the research funded, creating gaps for research at the low/mid-level of technological readiness. Interviewees also considered that the road mapping exercise of PPPs could be strengthened by adopting more advanced scenario-based approaches to better address long-term strategic objectives.

Directionality towards a digital and sustainable industry showed signs of increasing during the FP work programmes and specific calls as well as in the partnerships' SRIAs. Interviewees referred to regulations as important drivers for industry to embrace the SDGs. The human-centred approach to innovation and the fostering of responsible R&I were important concepts in the H2020 LEIT ICT and NMBP work programmes, including non-technological aspects and the broader ethical development of digital and industrial technologies. Integration of Social Sciences and Humanities expertise was, however, highly limited. Interviewees active in the field of manufacturing technologies saw a funding gap for topics addressing human aspects beside/beyond robotics and the need for more continuity in the funding, and more end-user participation (co-creation processes).

Coherence

Reflecting technological developments as well as the drive towards cross-fertilisation of the enabling technologies, the LEIT programmes created significant interconnections between the various programmes and their cPPPs. Connections between the intervention areas in the LEIT Space programme and between the LEIT Space and the LEIT ICT and NMBP appeared weaker, due to the strong differences among its intervention areas and the rather limited integration of the Space programme in the digitalisation and industrialisation discourse. There was, however, an increase in alignment observed in the last programming period.

Based on the programme data at the DIT level and the investigations carried out at the programme level, the LEIT programmes created strong downstream synergies with the Societal Challenges Pillar and in the case of the LEIT ICT programme, upstream with the Excellent Science Pillar. Synergies between the LEIT NMBP and Space programmes and the H2020 Pillar I appeared to rely on the expertise and cross-participation by individual organisations ('bottom-up' coherence).

Collaboration mechanisms aimed at the creation of synergies between the partnerships were gradually put in place under H2020, especially as a component of the SRIA definition process. Interviewees attributed a high importance to ensuring coherence between the partnerships' SRIAs and the H2020 programmes. They saw the need for more formal mechanisms and a more transparent and better-coordinated process with a clear timetable to align their roadmapping exercises with the work programmes and translate the SRIAs into call topics. They also emphasised the increasing complexity of this process and recommended the establishment of a dedicated governance platform.

External coherence with national and regional funding programmes was facilitated by the public-to-public partnerships in the field of advanced materials and metrology and in the field of Space technologies, strong collaboration with the European Space Agency (ESA), and the creation of complementarities with the Copernicus and Gallileo programmes. In addition, strong efforts were undertaken to enhance the collaboration and create synergies in the field of ICT and NMBP, among others, by using the European Structural and Invest Fund (ESIF). Difficulties were encountered to achieve these synergies, mainly due to the mismatch of different programme timeframes.

EU added value

Survey respondents indicated a high level of 'additionality' compared to other possible funding sources, in terms of the size of the funding as well as the scale of the projects and the speed of reaching the desired project results. The programme enabled a behavioural change towards more research-industry collaboration, while placing greater attention on the societal challenges in the organisations' own research agenda. The programme was less successful in inducing a behavioural change towards the conduct of human-centred innovation research and fostering the willingness to conduct risky research.

The European dimension of the research funded was considered critical for the creation of multi-sectoral consortia, the cross-fertilisation of knowledge and knowledge exchange with the best performers in Europe, and access to new markets that are out of reach in the national environment.

Overarching conclusion

The overall conclusion is that the H2020 contributed to the Digital and Industrial Transition by responding to the changing landscape and supporting the development of radical breakthroughs and innovations. The emphasis on demonstrating, and lowering the risk of investments in, Key Enabling Technologies, including for the creation and strengthening of knowledge ecosystems, the development of infrastructures and pilot lines, and the improvement of framework conditions, were critical from that

perspective. The increased input from industry actors and technological experts in the programming process ensured a stronger alignment with the needs of the targeted industry sectors and end-users, setting the conditions towards genuine transformation.

Throughout H2020, a key area of improvement was the greater policy coordination with Member States observed in the later stages of the Framework Programme and under continuing H2020's successor, Horizon Europe. Another observation was that the LEIT programme's effectiveness could be underestimated due to lack of data. There is also a clear need for the FP Monitoring and Evaluation System to be enhanced in order to better assess the FP's performance in the context of a transformative R&I policy. In addition, seeing the timing of this evaluation (at a time when LEIT projects that had concluded their activities accounted for (only) 53% of the funding), a H2020 ex-post evaluation collecting longer-term data once all projects are concluded, is needed to reach a full view of the H2020 contributions to DIT and draw all lessons to be learned.

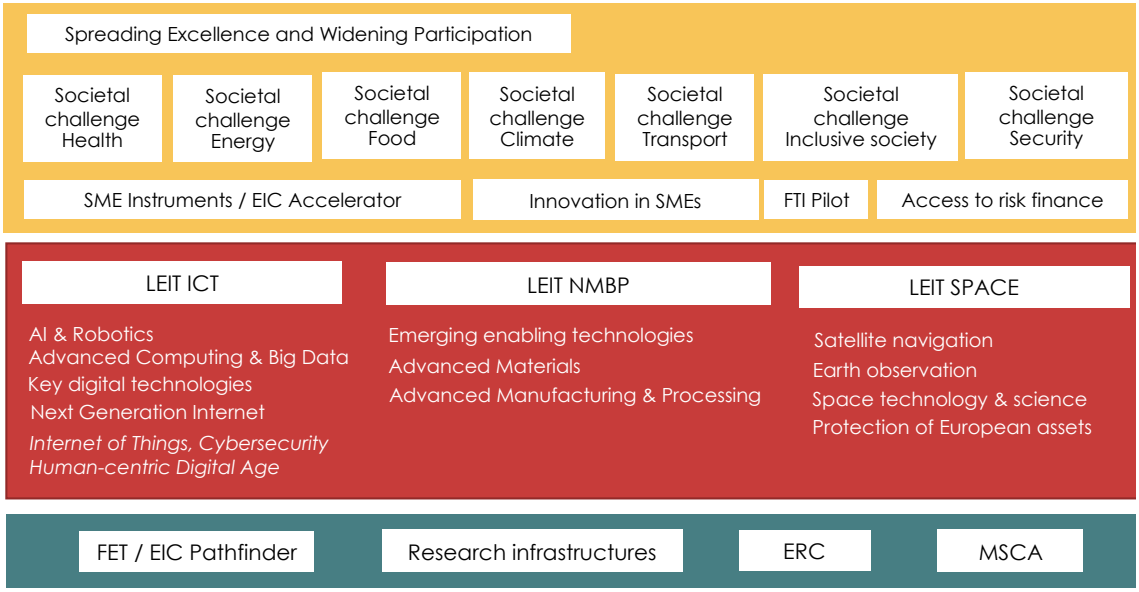
1. Introduction

This final report provides the results of Phase 1 in the 'Evaluation Study on the European Framework Programmes for Research and Innovation for Addressing Global Challenges and Industrial Competitiveness – Focus on Activities for the Digital and Industrial Transition'. The evaluation was implemented in the period January 2022 – November 2022 by a consortium consisting of Technopolis Group, AIT, Fraunhofer ISI, and Science-Metrix.

The objective of the first phase in the study was to evaluate the contribution of the Horizon 2020 Framework programme to the Digital and Industrial Fransitions and feed into its ex-post evaluation. The overall aim was to identify what worked well and less well, capture any lessons to be learned, and make suggestions for improvements that might benefit the short and long-term performance of the Framework Programmes going forward.

The evaluation considered all activities under H2020 that contributed to the Digital and Industrial Transition, funded under any of the H2020 Pillars and Priorities (Figure 1). At its core was the H2020 'European leadership in enabling and industrial technologies' programme part under the Industrial Leadership Priority, encompassing sub-programmes or 'intervention areas' and cross-cutting issues. The scope also included the related public-private and public-public partnerships and EIT KICs.[17]

Figure 1 Scope for the analyses in Phase 1 of the evaluation



Source: Technopolis Group

The report is structured as follows:

- Chapter 2 sets the background to the study, including the description of the H2020 DIT activities, intervention logic and objective hierarchy, the baseline, the evaluation questions (and their coverage throughout the report) as well as the methodological approach.
- Chapter 3 provides an overview of the implementation state of play.
- Chapters 4 to 8 present the key findings along the main evaluation criteria of relevance, efficiency, effectiveness, coherence, and EU added value.
- Chapter 9 covers the key findings, conclusions, lessons learnt and suggestions for improvement.

The report has the following appendices: Appendix A defines the codes and categories used for structuring the analyses and presents the frameworks used for the assessment of the FP contributions

[17] As agreed with the EC, the cPPP BBI and cPPP EEB projects as well as the cPPP Cybersecurity projects in non-LEIT programmes are excluded since these projects/cPPPs are covered in other H2020 evaluations.

to transitions, Appendix B provides a structured overview of the evaluation questions, and Appendix C presents the main conclusions and recommendations at the LEIT programme level.

The Annexes to this report (separate document) set out the findings from our analyses in detail and describe the specific methodological approaches. They are:

- Annex I: Case studies report (including the findings of the cross-analysis)
- Annex II: Partnerships report (including the findings of the cross-analysis by type of partnership)
- Annex III: International benchmark cases report (including the findings of the cross-analysis)
- Appendix IV: Data analytics on IPR and innovation
- Appendix V: Bibliometrics
- Appendix VI: Analysis of efficiency
- Appendix VII: Synopsis report (including the results of the stakeholder consultations, i.e. the interviews conducted and the targeted stakeholder consultation (survey))
- Appendix VIII: Evidence table

2. Background

In this chapter we first set out the policy context behind H2020's contribution to Digital and Industrial Transition, describe the H2020 and LEIT programme part objectives, and the H2020 intervention logic related to its contributions to DIT. Section 2.2 sets the baseline. The evaluation questions addressed in the study and the methodological approach are covered In Section 2.3.

2.1. Policy context, objectives, and intervention logic

2.1.1. The evolving policy context behind Horizon 2020 and the LEIT programme part

Horizon 2020 has marked a fundamental change in European policymaking due to its comprehensive approach to research and innovation. It was the first FP to be integrated explicitly into a wider system of policymaking, namely the **Europe 2020 (EU2020) Strategy** for a smart, sustainable, and inclusive growth. Research and innovation were considered key factors to attain the objectives of EU2020 flagship initiatives, such as the Innovation Union, Resource-Efficient Europe, An Industrial Policy for the Globalisation Era, and Digital Agenda for Europe, as well as the climate and energy policy. Cohesion policy also had a key role to play in terms of capacity-building and providing a 'stairway to excellence'.

The financial and economic crisis in 2008/09 was a strong accelerator for industrial research funding under H2020. It set the background for the 2012 European **Key Enabling Technologies (KETs) Strategy[18].** The strategy was structured around three pillars: technological research, product demonstration, and competitive manufacturing activities. The strategy was reviewed and updated in 2018 by an independent High-Level Group on Industrial Technologies[19] who defined new KETs, proposed exemplary missions for Europe, and suggested actions to improve the overall innovation system.

In 2015, the new Juncker Commission set out a **comprehensive strategic framework** of initiatives aimed at strengthening the overall competitiveness of industry, especially small and medium-sized enterprises. This included the Investment Plan for Europe, the Energy Union, the Capital Markets Union, the Circular Economy Package, and the Single Market Strategy, complemented by sector-specific measures like in the case of steel, space and defence industries.[20] The ten Juncker Commission policy priorities included a new boost for jobs, growth and investment, a connected Digital Single Market

[18] EC (2012) A European strategy for Key Enabling Technologies – A bridge to growth and jobs, Communication from the Commission COM(2012) 341 final.
[19] EC (2018) Re-Finding Industry – Defining Innovation. Report of the independent High-Level Group on industrial technologies, European Commission, DG Research and Innovation.
[20] EC (2016) Digitising European Industry – Reaping the full benefits of a Digital Single Market, COM(2016) 180 final.

(DSM), a deeper and fairer internal market with a strengthened industrial base, and Europe as a stronger global actor. Commissioner Moedas set out three priorities for the EU R&I policy: Open Science, Open Innovation, and Open to the World. The Open Innovation priority aimed at helping Europe to capitalise on the results of research and innovation and create shared economic and social value by bringing more actors into the innovation process, boosting investment, maximising the impact of innovation, and creating innovation ecosystems. The Digital Single Market Strategy[21] considered the attainment of this policy priority to be a prerequisite for attracting investment in digital innovations and accelerating business growth in the digital economy.

The policy developments leading to the definition of the **EU Industrial Strategy** entailed a series of Communications and Council decisions. In 2016, the Communication Digitising European Industry – Reaping the full benefits of a Digital Single Market introduced a set of coherent policy measures as part of a DSM technologies and Public Services Modernisation Package, aimed at building upon, complementing, and ensuring the scaling-up of national initiatives. Responding to the need for a holistic and forward-looking vision for Europe's industry, the Renewed EU Industrial Policy Strategy was launched in 2017.[22] It called for a joint commitment and important systematic efforts on the part of industry as well as all relevant EU, national and regional stakeholders "to maintain and reinforce Europe's industrial leadership in the age of globalisation, sustainability challenges and rapid technological change, and reap the vast opportunities of the new industrial age". In 2019, the Council adopted the Conclusions 'Future of a highly digitised Europe beyond 2020: Boosting digital and economic competitiveness across the Union and digital cohesion',[23] calling for "a European policy that both supports innovation and fosters the European key digital technologies, not only enabling the development and use of artificial intelligence, but also ensuring its integration into the internal processes of companies of all sizes: start-ups, SMEs, and scale-ups, and also ensuring international cooperation so that Europe becomes a world leader in this sector". Finally, building on the progress towards a fully functioning Digital Single Market, the European Commission presented in March 2020 a New Industrial Strategy for Europe, aimed at setting the way for EU industry to lead the twin green and digital transitions. Influenced by the international political developments after 2017, the strategy also responded to concerns regarding the technological sovereignty of Europe.

The European Commission defined its **EU Space Strategy** to help in addressing Europe's social, economic, and strategic challenges through a series of policy developments. In April 2011, the Communication 'Towards a space strategy for the European Union that benefits its citizens'[24] positioned space among the priorities of Europe 2020. Subsequently, in February 2013, the Communication on the 'EU space industrial policy: Releasing the potential for growth in the space sector'[25] set the objectives of LEIT Space. Finally, in 2016, the Communication 'Space strategy for Europe'[26] set out the intention to a) step up EU efforts to support space R&D activities and review its strategic approach to boosting the competitiveness of the European space sector, b) promote, together with Member States and ESA, the use of common technology roadmaps to improve the complementarity of R&D projects, and c) with regards to EU access to space, support R&I to ensure Europe's ability to anticipate and react upon disruptive changes. In 2021, the Council and European Parliament adopted a regulation establishing the new EU Space Programme for the years 2021 to 2027.[27] It simplified the EU legal framework and governance by setting existing EU programmes such as Copernicus, Galileo and EGNOS under one umbrella.

2.1.2. Objectives and intervention logic for the H2020 contribution to DIT

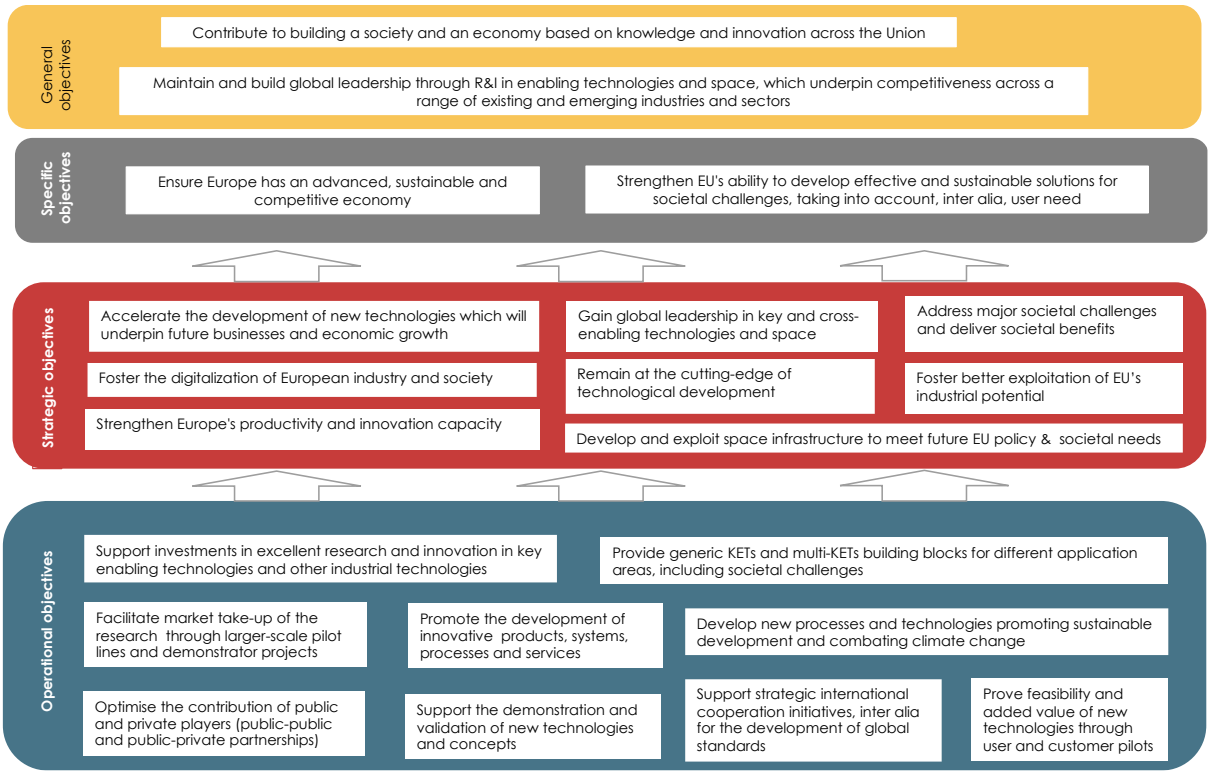
According to the Regulation[28], the **general objective** of Horizon 2020 was "to contribute to building a society and an economy based on knowledge and innovation across the Union by leveraging additional research, development, and innovation funding and by contributing to attaining research and development targets, including the target of 3% of GDP for research and development across the Union by 2020." The FP was to support the implementation of the EU2020 strategy and other EU policies, as

[21] EC (2015) A Digital Single Market Strategy for Europe, COM(2015) 192 final.
[22] EC (2017) Investing in a smart, innovative and sustainable Industry – A renewed EU Industrial Policy Strategy, COM(2017) 479 final, Brussels, 13.9.2017.
[23] EU (2019) Council Conclusions on the Future of a highly digitised Europe beyond 2020: 'Boosting digital and economic competitiveness across the Union and digital cohesion', 10102/19.
[24] COM(2011)152
[25] COM/2013/0108 final
[26] COM(2016) 705 final
[27] Regulation (EU) 2021/696 of the European Parliament and of the Council of 28 April 2021 establishing the Union Space Programme and the European Union Agency for the Space Programme and repealing Regulations (EU) No 912/2010, (EU) No 1285/2013 and (EU) No 377/2014 and Decision No 541/2014/EU.
[28] European Union (2011) Regulation of the European Parliament and of the Council establishing Horizon 2020 – the Framework Programme for Research and Innovation (2014-2020) and repealing Decision No 1982/2006/EC.

well as the achievement and functioning of the European Research Area (ERA). 'Horizontal' objectives for all programmes funded under H2020 included the conduct of responsible research and innovation and international cooperation. The promotion of sustainable development, in a broad sense, and combating climate change was to be fully integrated in all Horizon 2020 priorities.

The **specific objectives** of H2020 were defined at the programme level. The objective of the LEIT programme part was "to **maintain and build global leadership** through research and innovation in enabling technologies and space, which underpin competitiveness across a range of existing and emerging industries and sectors." Figure 2 gives a comprehensive view of the **key strategic and operational objectives** for all programmes in the LEIT programme part.

Figure 2 Objectives hierarchy of the LEIT programme part



Source: Technopolis Group, based on the H2020 Regulation and the H2020 Council Decision[29]

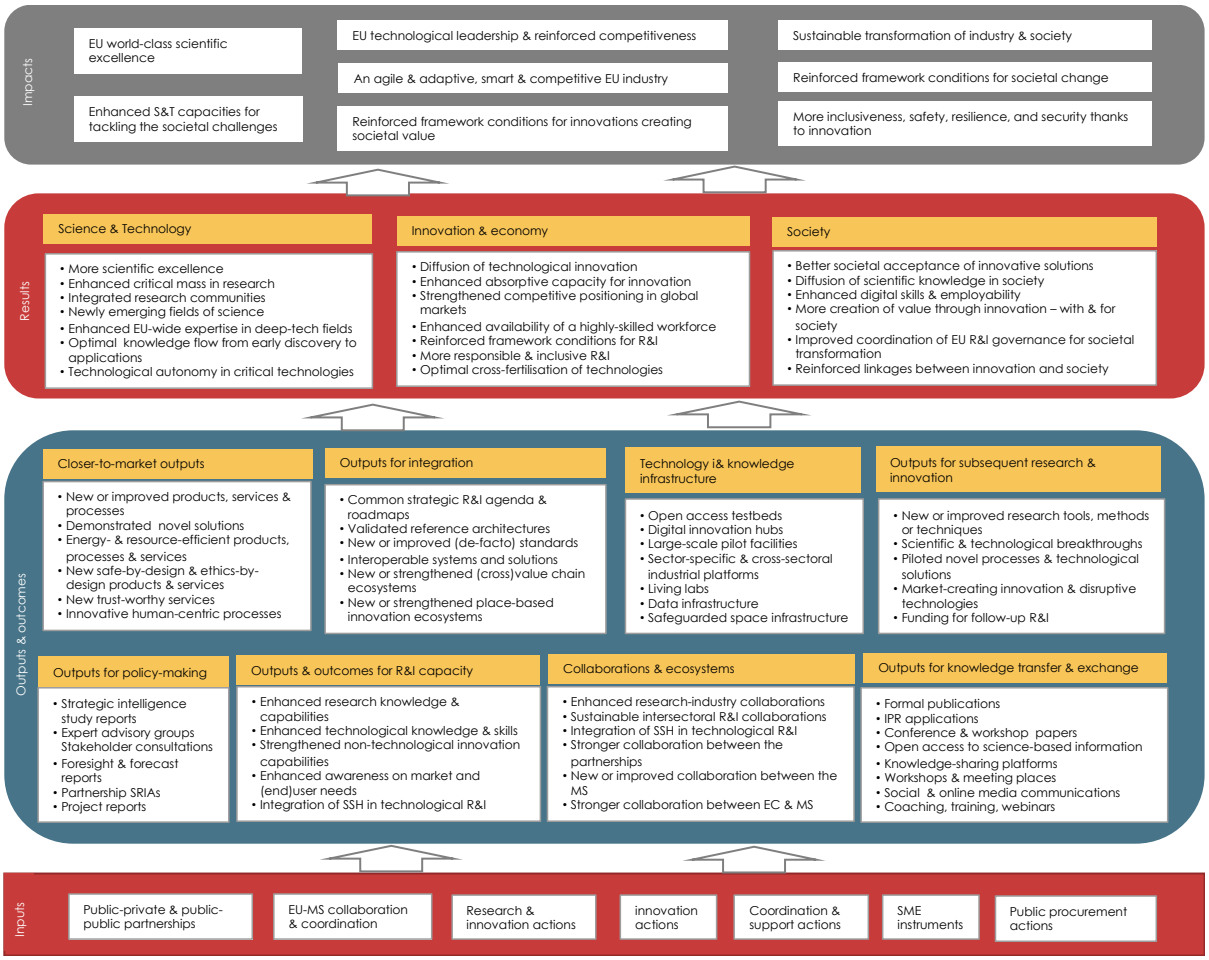
The LEIT ICT programme was to contribute to Europe gaining global leadership in digital technologies and exploiting the opportunities brought by ICT progress, the LEIT NMBP programme was primarily to scale up technologies and reduce lead time to market. The LEIT Space programme was expected to strengthen the competitiveness, non-dependence, and innovation of the European space sector, enabling advances in space technologies, the exploitation of space data, and the contribution to international space research partnerships.

Activities funded under the LEIT programme part were primarily to be based on research and innovation agendas, "mainly defined by industry and business, including SMEs, together with the research community and Member States in an open and transparent manner, and have a strong focus on leveraging private-sector investment and on innovation." Innovation was to be exploited in the widest sense, including business, organisational and social aspects.

Figure 3, below, maps out the **intervention logic** for the Framework Programme contribution to the Digital and Industrial Transition.[30]

[29] Council Decision establishing the specific programme implementing Horizon 2020 – the Framework Programme for Research and Innovation (2014-2020), Brussels, 22 November 2013.
[30] The intervention logic reflects the intervention logic and impact pathways set out for H2020, taking account of the objectives set for the LEIT programme part and the key concepts in the scientific literature and EU and OECD policy papers on transformative R&I policy and transitions.

Figure 3 Intervention logic for the Framework Programme contribution to the Digital and Industrial Transition



Source: Technopolis Group, 2022

2.2. Baseline

2.2.1. LEIT-related research under FP7

FP7 funded the research areas covered in the H2020 LEIT ICT, NMBP and Space programmes in the context of its Cooperation Programme, providing for 'transnational cooperation' in ten thematic areas. These included Information and communication technologies (ICT), Nanosciences, nanotechnologies, materials, and new production technologies (NMP), and Space.

It should be noted that under FP7, innovation-oriented activities (including some applied R&I activities) were funded under a separate programme, the Competitiveness and Innovation Framework Programme (CIP). Small and medium-sized enterprises (SMEs) were the main target of the programme. One of its three operational programmes was the ICT Policy Support Programme (PSP), aimed at encouraging the take-up and use of ICT, and helping to develop the information society.

2.2.2. Baseline and key performance indicators for the LEIT programme part

The H2020 Council Decision[31] defined three key performance indicators (KPI) for the monitoring and assessment of the results and impacts of the Leadership in Enabling and Industrial Technologies priority.

[31] Council Decision establishing the specific programme implementing Horizon 2020 – the Framework Programme for Research and Innovation (2014-2020), Brussels, 22 November 2013.

Table 1 lists those indicators, also showing the baseline and target values indicated in the EC H2020 Programme Statement.[32]

Table 1 Key performance indicators for the LEIT-specific objective

	Baseline (2013)	Target (2020)
Indicator 1: Patent applications and patents awarded in the different enabling and industrial technologies		
Patent applications in the different enabling and industrial technologies per €10 million funding	ICT (FP7: 0.9) NMBP (FP7: 2.0) Space (FP7 Cooperation projects: 0.3)	3.00
Indicator 2: Share of participating firms introducing innovations new to the company or the market (covering the period of the project plus three years)	none	
Indicator 3: Number of joint public-private publications	none (no comparable data for FP7)	

Source: EC Programme Statements, 2020

2.3. Evaluation questions and methodology

2.3.1. Evaluation questions and criteria

In total, 45 evaluation questions were defined for this study, structured around the evaluation criteria of relevance, coherence, efficiency, effectiveness, and EU added value. Ten additional questions specifically regarded the partnerships. Some evaluation questions were, however, indicated in the ToR as being relevant only for the Horizon Europe evaluation.[33]

Table 2 lists the topics of investigation addressing the evaluation questions for H2020. It also indicates the sections in this report where we report on the findings. The full list of questions is provided in 0 to this report. The evaluation log provided in Annex VIII (separate document) provides further details.

Table 2 Evaluation criteria and topics for investigation in the evaluation questions

Criterion & question		Topics of investigation	Report section
RELEVANCE	1,	Alignment with stakeholders' needs and scientific, technological and/or socio-economic problems and issues	4.1.1
	2	Alignment with the latest technological, scientific and/or socio-economic developments and coverage of emerging needs	4.1.1
	3	Reflection of the positioning of the European Union in this area over time	4.2.3
	4	Alignment with the needs of groups targeted for application/participation	4.1.2
	5	Flexibility to cope with changing circumstances in Europe and the world?	4.1.1
	6	Relevance of the objectives of the partnerships	4.2

[32] EC (2020) Draft general budget of the European Union for the financial year 2021, Programme Statements of operational expenditure, Working Document Part I, COM(2020) 300, available at https://commission.europa.eu/system/files/2020-06/2020-06-24_db2021_wd1_programme_statements.pdf.

[33] The ToR also stated that data collection and analysis on the FP relevance and coherence evaluation questions as well as the questions regarding internationalisation would be covered by other studies running in parallel, using a back-to-back approach. These questions were therefore not part of this investigation. The study team nevertheless collected (some) evidence against those criteria, seeing their importance for a quality evaluation (for example, in relation to the enabling factors for effectiveness).

EFFICIENCY	**1**	**Efficiency of implementation processes in terms of administration and management, project application and selection processes, funding allocation, forms of implementation** **Catering for flexibility needs in implementation** **Experience of applicants and participants at application stage and during the implementation of the projects** **Project application, management, and reporting performed by organisations other than those performing the research and innovation activities**	**5.1.1** **5.1.2** **5.1.3** **5.1.4**
	2	Cost-effectiveness Proportionality of costs of application and participation – compared to previous FPs	5.2.1 5.1.2
	3	Efficiency FP monitoring and evaluation systems and feedback to policy processes programme communication/valorisation strategy	5.1.5
	4	Cost-effectiveness of the partnerships	5.2.2
EFFECTIVENESS	1	Main results and (expected) outcomes and scientific, economic and societal impacts Achievement of the programme's objective(s) Internal or external factors influencing progress Determinants for success/failure in advancing the state of the art and/or the maturity of technologies Effectiveness of dissemination, exploitation and communication measures	6.2.1 6.2.2 6.2.3 6.3.1 6.3.2 6.3.2
	2	Contribution to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)	6.2.3
	3	Effectiveness in advancing the state of the art, extent to which results are exploited Effectiveness in advancing advance the maturity of technologies International cooperation making a difference	6.2.1 6.2.2 6.3.2
	4	Partnerships effectiveness and contribution to the FP objectives	6.2.5 6.3.4
	5	Contribution to more sustainable (greener), resilient and human-centric industry	6.2.3
	6	Technological developments and collaborations that have a dual use Cases with unethical or against human rights activities	6.3.3
	7	Projects proposing tangible improvements and reforms of skills in workforce and curricula for educational establishment/universities	6.3.1
	8	Bottom-up schemes with open calls (ERC, FET-Open, MSCA, EIC- Pathfinder, etc.) contributing to the identification and early leadership in new and emerging enabling technologies	6.2.1
	9	Activities and outputs of the funded actions (projects, partnerships and other) contributing to making European industry more sustainable (greener), resilient and human-centric	6.2.3
COHERENCE	1	Coherence between Framework Programme parts covered by this study and with other parts of the Framework Programme	7.1.1
	2	Coherence among partnerships, and between partnerships and the Framework Programme activities	7.1.2
	3	Coherence with other EU programmes serving similar objectives Positioning of the Framework Programme in this area within the overall European research and innovation landscape	7.2.1 7.2.2 7.2.3
EU ADDED VALUE	1	Additionality of the FP	8.1
	2	Additional value of the partnerships in contributing to the Digital and Industrial Transition	8.2
	3	EU added value of the FP to support the Digital and Industrial Transition	8.3

PARTNERSHIPS	**1**	**Mobilisation of private and/or public R&I contributions**	**5.2.2**
	2	Facilitating the creation and expansion of R&I networks	6.3.1 6.3.4
	3	Openness to new participants, to new members, openness in use of research result accessible for SMEs	6.3.4

2.3.2. Methodological approach

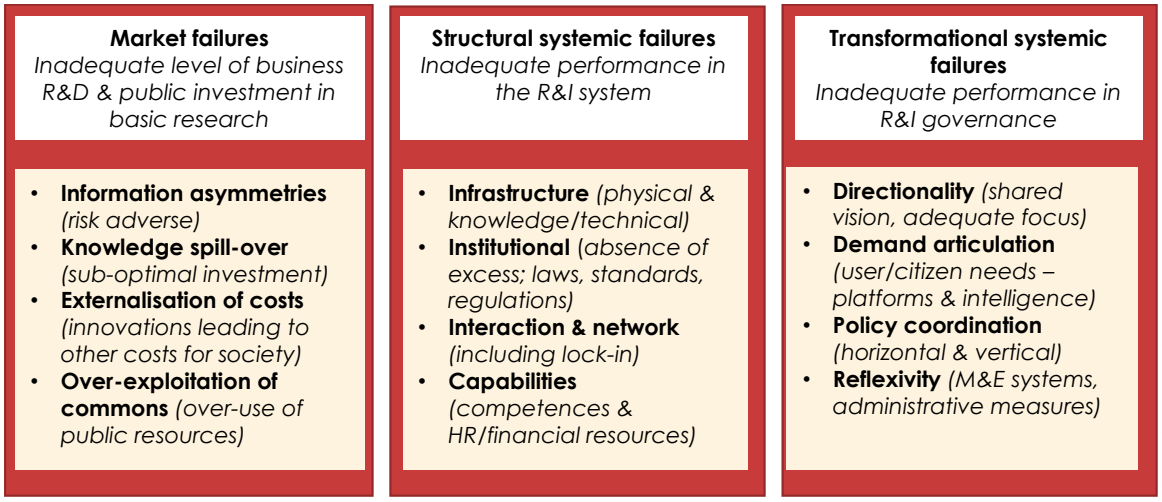
The evaluation findings summarised in this report build upon a broad mix of qualitative and quantitative data collection and analysis methods, listed in Table 3. The coloured cells indicate the relevance of a method for the evaluation questions in the criteria categories (darker shadings stand for a higher degree of relevance). The annexes to this report (separate documents) provide more information on the methodological approach (see Chapter 0, above).

Table 3 Methods used to address the questions under the evaluation criteria

	Relevance	Efficiency	Effectiveness – Achievements	Effectiveness – Enabling factors	Coherence	EU added value	Partnerships specific criteria
Desk research							
Interviews (217 in total)							
Stakeholder survey (participants and unsuccessful applicants scoring above threshold)							
Portfolio & composition analysis (CORDA, EIT KICs, P2Ps)							
Statistical data analyses (InnoRadar, Crunchbase)							
STI data analytics – bibliometrics & IPR data analyses							
Social Network Analysis							
Case studies (15) & international benchmark cases (4)							
Cross-analyses of the case studies, international benchmark cases, and partnership assessments							
Meta-analysis of the back-to-back studies							

The **taxonomy of failures** justifying public interventions which takes account of the new challenges posed by the transitions concept and transformative R&I policy in general acted as a key conceptual framework to structure the data collection and analysis throughout this study (Figure 4). A full description of the taxonomy is provided in Appendix A2.

Figure 4 Three generations of 'failure' justifications for public support initiatives for R&I



Source: Technopolis Group

3. State of play

In this chapter we first provide an overview of the implementation of H2020 activities contributing to DIT, and then cover the LEIT programme part in Section 3.2. More details on the latter are provided in Chapter 5 and Annex VI to this report (separate document).

3.1. H2020 contribution to DIT

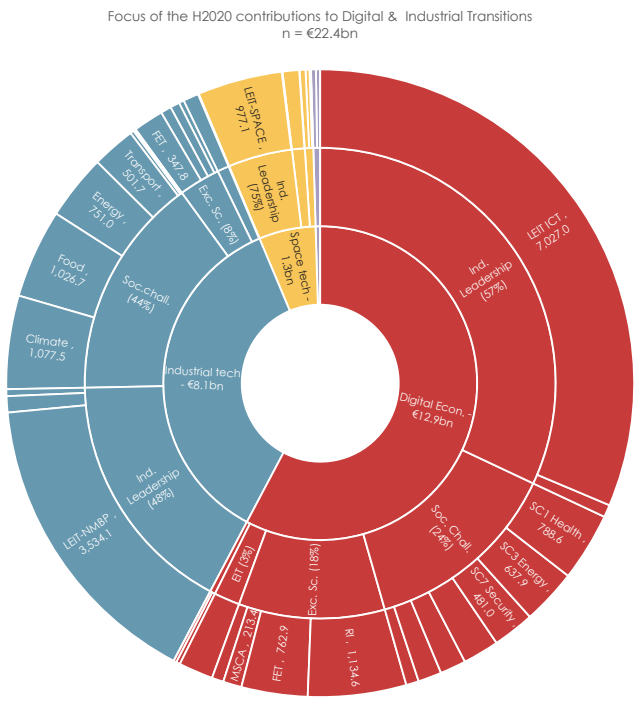
Based on our analysis of the CORDA data (reference date: 15 November 2021), we estimate that H2020 funded in total **6,484 projects** in contribution to the Digital and Industrial Transition, accounting for an EU contribution of **€22.4bn** or **33%** of the total H2020 budget.[34] About 45% of the total budget was distributed in the 2018-2020 Work Programme, funding about 30% of the projects.

Overall, the Digital Economy was the most prominent research area, accounting for about 60% of the H2020 contributions to DIT and close to 20% of the total H2020 funding. R&I activities focused on Industrial Technologies accounted for about 30% of the H2020 contributions to DIT, Space Technologies for about 2%. Figure 5 shows the share of the contributions in the H2020 priorities and programmes.

The Digital Economy research area was supported mainly through R&I activities in the Industrial Leadership priority (about 60% of the budget), predominantly so in the LEIT ICT programme (Figure 5). A broad range of societal challenges were addressed, with a particular focus on the Health and Energy challenges (26% and 21% of the funding, respectively). Excellent Science research, accounting for about 20% of the budget, contributed mainly through research in the Research Infrastructures and FET programmes (50% and 34%, respectively). EIT Digital accounted for 3% of the funding.

[34] Projects relevant for the Digital and Industrial Transition area beyond the LEIT programme part were selected based on the description of the area in the ToR, *information in CORDIS* on H2020 projects relevant for the Digital Economy, Industrial Technologies and Space technologies, *text mining* of the H2020 topic and call descriptions, *references* in the LEIT work programmes to ICT-, NMBP- or Space-related calls in other H2020 programmes, relevant *policy markers* in the CORDA monitoring data, and a text mining of the publications deriving from ERC Proof of Concept and MSCA ITN-EID projects. The selected dataset includes all activities funded in the context of the relevant cPPPs, JUs, and EIT KICs (see Chapter 0). The P2Ps are not included because not funded under the FP.

Figure 5 Distribution of the H2020 contribution to DIT over the research areas



Industrial Technologies were supported predominantly in the Industrial Leadership and Societal Challenges pillars (48% and 44% of the funding, respectively). The LEIT NMBP programme accounted for 93% of the funding in the Industrial Leadership priority. The focus in Societal Challenges was mainly on the fields of Food and Climate (30% of the funding, each), and energy (20%). Excellent Science support accounted for 8% of the funding, provided mainly in the FET programme (55%), followed by MSCA (19%). The EIT Raw Materials accounted for 2%.

Space Technologies were mainly supported in the Industrial Leadership pillar (75% of the funding). Support for the Societal Challenges (15%) focused close to exclusively on the Climate challenge. Excellence Science support (10%) was provided in the RI and FET programmes (52% and 35% of the budget, respectively).

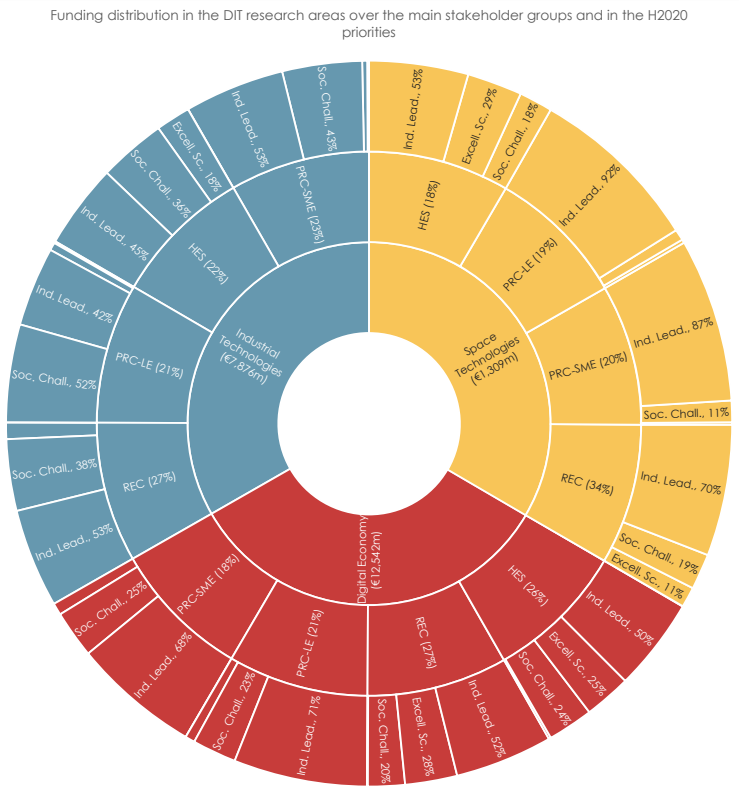
Source: Technopolis Group, based on CORDA data (15/11/2021)

The H2020 projects contributing to DIT accounted for a total of **60,279 participations**, of which about 60% were in the Digital Economy area, 35% in the Industrial Technologies area, and 5% in the Space Technologies area.[35] EU funding was distributed in a close-to-equal manner among the main stakeholder groups: 23% for Higher Education Institutions (HES), 21% for Research Organisations (REC), 22% for Large Enterprises (LE), and 23% for SMEs. Public Administration bodies accounted for 4%, the 'Other' organisations for 6%.[36]

Figure 6 shows the funding distribution over the stakeholders in the three DIT areas.

[35] Participation data for the EIT KICs are excluded because of their incompatibility with the stakeholder categorisations used in the CORDA database.
[36] Data on SMEs are based on specific indications in CORDA. Private enterprises not flagged as SMEs are categorised as Large Enterprises.

Figure 6 Stakeholder funding in the DIT research areas



Source: Technopolis Group, based on CORDA data (15/11/2021)

The Digital Economy area showed a close-to-equal funding for the HES and REC, accounting for around 30% of the budget each. Industry actors accounted for about 40%, with a close-to-equal split between LEs and SMEs.

In the Industrial Technologies area, HES and REC accounted for nearly 50% of the funding. with the highest share (27%) going to the latter. Industry actors accounted for 44%, also in this area close to equally split between LEs and SMEs.

Research Organisations were the main stakeholders in the Space Technologies area (34% of the funding). HES accounted for 18%, and the private sector for about 40% of the funding, close-to-equally split between SMEs and LEs. Public Administrations actors accounted for 6% of the budget.

3.2. The H2020 LEIT programme part

The LEIT programme part was at the core of the H2020 contributions to DIT. In total, **3,161 projects** were funded under the LEIT programme part with an EU contribution of **€10.3bn**.[37]

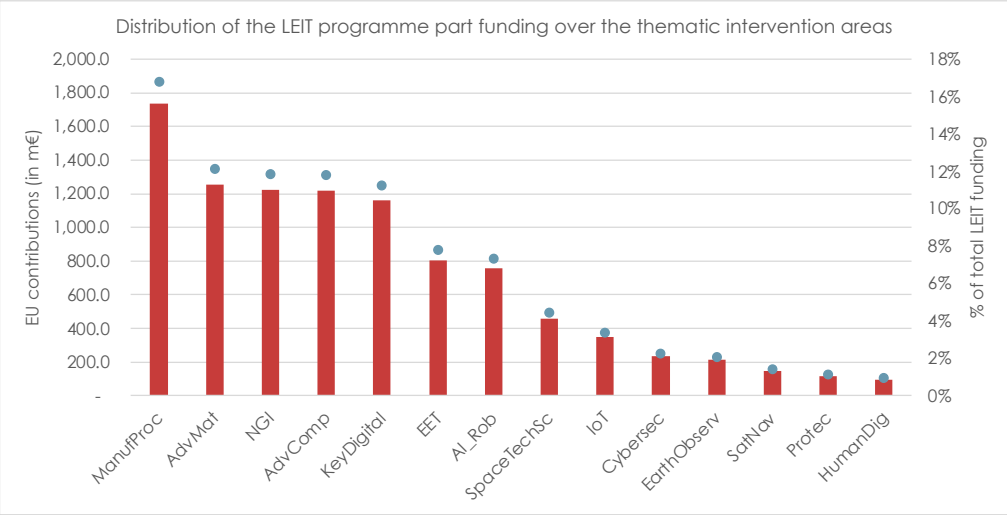
3.2.1. Funding distribution over programmes and intervention areas

The LEIT ICT programme was the largest programme in the H2020 LEIT programme part. Its 1,802 projects accounted for about 55% of the total LEIT project portfolio. The LEIT NMBP programme accounted for about 30% (951 projects), while the 456 projects in the LEIT Space programme represented a share of about 15%. The LEIT ICT programme had a budget of €5.8bn or 55% of the total LEIT programme part budget. The LEIT NMBP programme accounted for about 35% (€3.5bn) and the LEIT Space programme for about 10% (€0.98bn).

Figure 7 shows the distribution of the funding over the **technological intervention areas** in the LEIT programme part. The highest share of the budget (17%) was dedicated to the Manufacturing & Processing Technologies intervention area, funded under both the LEIT NMBP and the LEIT ICT programmes (13% and 4% of the budget, respectively). Advanced Materials, Next-Generation Internet, Advanced Computing, and Key Digital Technologies followed with 12% of the budget each. The Emerging Enabling Technologies (EET) and Artificial Intelligence & Robotics areas accounted for about 7%. At the lower end we find the LEIT Space intervention areas: Space Technologies & Science accounted for 4%, Earth Observation for 2%, Satellite Navigation and Protec for 1%. The LEIT ICT 'cross-cutting' areas Internet of Things (IOT), and Cybersecurity accounted for 3% and 2% of the budget, respectively.

[37] Data include only the projects funded through the calls under the LEIT programme part. The Joint Undertakings, EIT KICs and P2Ps are therefore excluded.

Figure 7 Distribution of H2020 contributions over the LEIT technological intervention areas



Notes: The field of Industrial Biotechnology (with a budget of about €350 million from LEIT-NMBP) has been covered in the H2020 Evaluation Study on Green Transition
Source: Technopolis Group, based on CORDA data (15/11/2021)

3.2.2. Stakeholder participation and funding

In total, there were **27,474 participations** in the LEIT objective by **11,323 individual organisations**. Each organisation therefore had on average 2.5 participations in projects. The Industry sector accounted for most individual participants, specifically SMEs for 43% and LEs for 30%. Large Enterprises were on average involved in 2.3 projects per organisation, SMEs on average in 1.7 projects.

Research Organisations were the main beneficiaries, accounting for about 30% of the LEIT programme part budget. They were closely followed by the three other main stakeholder groups that had a close to equal funding share (between 21% and 23%).

The LEIT ICT programme stands out for its balanced distribution of the budget over the main stakeholder groups, only slightly higher for the Research Organisations. LEIT NMBP and LEIT SPACE, instead, stand out for the high share of funding allocated to the Research Organisations. The H2020 target of minimal 20% of the funding allocated to SMEs was over-reached in all LEIT programmes.

Table 4 Distribution of the EU funding across stakeholders in the LEIT programme part

	Total LEIT objective		LEIT ICT		LEIT NMBP		LEIT Space	
	EU funding (in m€)	%	EU funding (in m€)	%	EU funding (in m€)	%	EU funding (in m€)	%
HES	2,344.8	23%	1,457.6	25%	761.7	22%	125.5	13%
REC	2,793.0	27%	1,417.0	24%	1,087.2	31%	288.8	30%
PRC_LE	2,174.0	21%	1,270.8	22%	668.0	19%	235.2	24%
PRC_SME	2,405.0	23%	1,293.6	22%	881.5	25%	229.9	23%
OTH	386.3	4%	280.5	5%	88.6	3%	17.2	2%
PUB	217.0	2%	89.5	2%	47.1	1%	80.5	8%
Total	10,320.1	100%	5.808.9	100%	3,534.1	100%	977.1	100%

Source: Technopolis Group, based on CORDA data (15/11/2021)

There were **11,048 participations by 'newcomers'**[38] in the LEIT programme part. Each newcomer organisation therefore participated on average in 1.6 projects. They accounted for 58% of all individual organisations participating in the LEIT programme part, for 40% of the total participations and for about 25% of the total funding. The LEIT NMBP programme was particularly successful in attracting new FP actors. In this programme, newcomers accounted for close to 40% of the total participations and for 30% of the funding.

Overall as well as in the specific programmes, more than 50% of the total SME participations were by newcomers. While turnover in the SME population is a typical phenomenon in the history of the FP, more surprising is the high share of newcomer participations among the Large Enterprises in the NMBP programme (54%), and among PA entities in the ICT and Space programmes (around 35% of the participations).

4. Relevance

This chapter reports on the evaluation criterion related to the relevance and the topics of investigation under each evaluation question. Section 4.1 covers the relevance in terms of S&T and socio-economic and stakeholder needs, including the challenges the programme means to address, its alignment with stakeholder needs and the competitive positioning of the European Union. Section 4.2 covers the relevance of the partnerships.

4.1. Relevance in terms of S&T, socio-economic developments and stakeholder needs

4.1.1. Alignment with S&T, socio-economic challenges and needs

S&T and socio-economic challenges over time

The rationale for the H2020 Pillar II 'Industrial Leadership', and specifically the LEIT programme part, lies in the **significant socio-economic challenges** that Europe faced in the aftermath of the 2008/2009 'Great Recession' and the euro area recession in 2011/2012, when several Member States faced a sovereign debt crisis. While signs of moderate recovery showed in 2014, the combined crises had significant consequences for Europe's economic growth, investment, and employment.

Major trends transforming our economies and societies in the last decade included increasing globalisation, with industry more integrated in global value chains, market disruptions, stronger concentrations and shifts in competitive power, and rising competition by non-European countries and new entrants. This posed a significant challenge for the EU manufacturing industry: the ICT sector faced strong global competition and market expansion by non-European countries – EU KET patents were increasngly exploited outside the EU. The space sector found itself at a crossroads because of increasing competition from newly emerging space-faring nations such as China and India.

Another major development was the rise in digital technologies and their convergence with the physical world, also called the Fourth Industrial Revolution or Industry 4.0, triggered by technological breakthroughs in areas like robotics, Internet of Things, artificial intelligence, energy systems and the bioeconomy. Automation, enabled by information technologies, was transforming traditional manufacturing processes and the nature of work. The distinction between manufacturing and services became more blurred, and data turned into the new competitive factor in our connected world. There was greater strain on natural resources and climate change, creating demand for sustainable products and circular consumption.[39] Finally, the Industry 5.0 concept emphasised the drive towards human-centred innovation, taking into account European citizens' needs and sensitivities.

Europe experienced a significant de-industrialisation since the launch of the globalisation era. Despite the potential for large productivity gains that the fast-developing digital technologies presented, this trend was only slowly reversed in the last decade. The critical importance of manufacturing to Europe's economy and welfare[40] – addressing societal challenges – triggered the EU2020 Strategy and Juncker

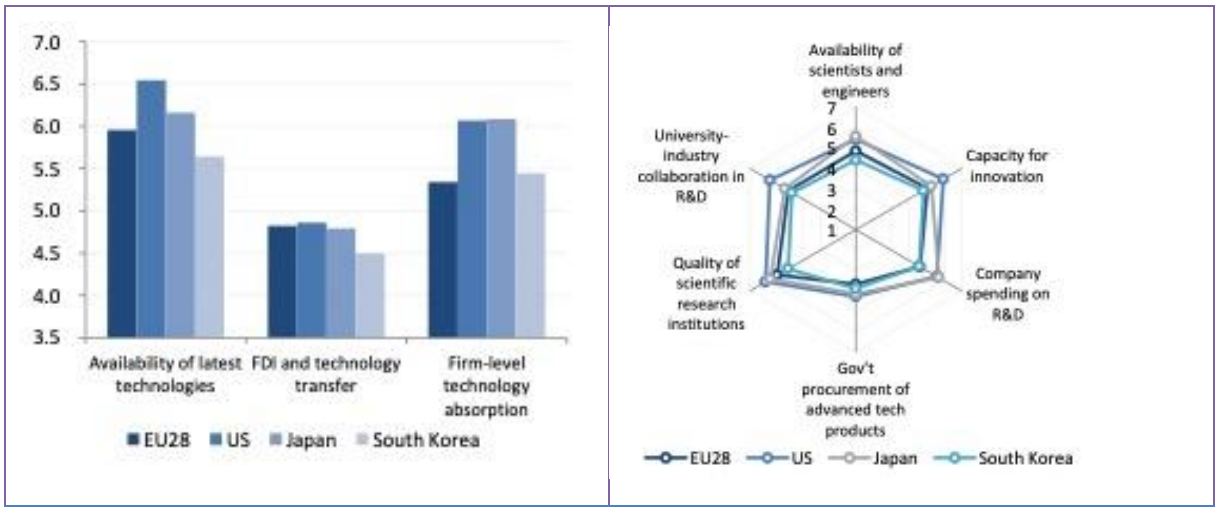
[38] Organisations that had not participated under FP7.
[39] EC (2017) Investing in a smart, innovative and sustainable Industry A renewed EU Industrial Policy Strategy
[40]. Every new job in manufacturing creates between 0.5 and 2 jobs in other sectors. More than 80 % of EU exports are generated by industry (EC, 2018).

Commission's priorities on stimulating Europe's re-industrialisation and digitalisation. Pillar II in the H2020 FP, and the LEIT programme part specifically, was designed to contribute to this objective.

In addition, combined with the challenging effects of the globalisation era, the geo-political situation in 2017 gave impetus to th need for greater technological sovereignty to safeguard European economic power and growth. Technologies relevant to digitalisation included robotics, microelectronics, high-performance computing, data cloud infrastructure, blockchain, quantum technologies, and photonics.[41] The EU Space Industrial Policy highlighted the importance of technological non-dependence, security of supply, and independent access to space as a basic condition for sustained development of Europe's space industry. It considered also that the security of critical European space infrastructure was not ensured since there was no full and accurate information about satellites and debris orbiting earth, which was considered a risk to space infrastructure.

The LEIT programme part was directed to address some of Europe's **long-standing structural weaknesses.** A notable challenge has been Europe's capacity to absorption innovation (see Figure 8). According to the European Investment Bank (EIB), key factors in the 'innovation environment' that influenced this difference in innovation capacity compared to the US, Japan or South Korea were the levels of university-industry collaboration and industry investment in R&D.[42] The ongoing innovation divide in Europe is an additional point of concern in this context.[43]

Figure 8 Technological readiness (left) and innovation environment (right) in the EU and leading economies



Note: Scores from 1 (worst) to 7 (best); EU28 GDP weighted average
Source: EIB (2016), based on World Economic Forum, Global Competitiveness Report 2015-2016

For European industry – and society at large – to reap the benefits of the digital age, its capacity to create and absorb innovation needs to be maintained and strengthened. Challenges in the S&T sphere requiring stronger capacities relate to the development speed (cycle) for enabling technologies and their increasing convergence and cross-fertilisation to address the needs of the cross-sectoral value chains. It also requires significant investments in education and high-level skills to boost Europe's workforce. The global race for talent implies that, for example, the automotive industry lacks science, technology, engineering, and mathematics (STEM) profiles and is facing stiff competition for skills from other sectors.[44] Compared to the US, the EU27 shows weaknesses in terms of availability of professionals with advanced technological skills in critical digital technology fields such cloud technologies, artificial intelligence, cybersecurity, big data and robotics, according to a recent EC report.[45] Strengths are in the

[41] EC (2020) A New Industrial Strategy for Europe, Brussels, 10.3.2020 COM(2020) 102 final.
[42] EIB (2016) Restoring EU competitiveness - 2016 updated version, Projects Directorate and the Economics Department of the EIB
[43] Firms located in Central and Eastern Europe tend to invest less in intangible assets, have a lower propensity to innovate, and are less productive than firms in Western and Northern Europe. Source: .EC (2020) Science, Research and innovation performance of the EU2020 – Productivity puzzle and innovation diffusion, Chapter 3.1, European Commission, DG R&I.
[44] EC (2018) Re-Finding Industry – Defining Innovation, Report of the independent High Level Group on industrial technologies, European Commission, DG RTD.
[45] Izsak, K., et al. (2021) Advanced Technologies for Industry – Final Report, Report on technology trends and technology adoption, Technopolis Group, IDC, Fraunhofer ISI, IDEA Consult. A study for the European Commission, European Innovation Council and SMEs Executive Agency (EISMEA)

fields of advanced manufacturing technologies, advanced materials, Internet of Things, and industrial biotechnology.

Responsiveness of the LEIT programme part

The mandate of the H2020 LEIT programme part was to address the structural and S&T challenges described above, with a pronounced focus on alleviating the economic and societal challenges that Europe was facing. From the literature and stakeholder interviews, different patterns emerged in terms of the importance and specific characteristics of these challenges in the three LEIT areas, depending on factors such as market structures and dynamics, technological maturity, and market readiness of the technologies.

Table 5, below, gives an overview of the **structural challenges** that required intervention in the LEIT programmes. We structured these challenges into a taxonomy of types of failures.[46] The coloured cells indicate which LEIT programmes addressed the specific types of failures, the degree of colour shading representing the level of importance.

The table shows that investments in R&I ('information asymmetries'), collaborations in the ecosystems ('network') and insufficient R&I capacities ('capability') were the most prominent failures, common to all LEIT programmes. All programmes also shared the need for more directionality and issues in policy coordination (the latter less so for the Space programme). The ICT and NMBP areas shared the need to address infrastructural, policy coordination, and institutional failures, while demand articulation was an issue in the NMBP and Space areas.

Table 5 Failures addressed in the fields of ICT, NMBP and Space

		ICT	NMBP	Space
Market failures	Information asymmetries	Reluctance to invest in risky R&D		
Systemic failures	Infrastructure failures	Lack of knowledge or physical infrastructures		
	Institutional failures	Standards & interoperability, regulations		
	Interaction or network failure	Insufficient cooperation between upstream and down-stream sectors, research-industry		
	Capability failures	Insufficient capacity, competences & skills		
Transformational failures	Directionality failure	Lack of shared vision		
	Demand articulation failure		Insufficient spaces for anticipating and learning about user needs	
	Policy coordination failure	Insufficient coordination creating risk of gaps and overlaps		

Notes: different shades of colour indicate the extent to which the failure was somewhat or especially prominent in the targeted technological areas and/or sectors
Source: Technopolis Group, based on EU policy papers and studies, and the H2020 Regulation and Council decision

The **approach chosen** to respond to these challenges and failures differed among the LEIT programmes. The LEIT ICT and LEIT NMBP programmes took a strong systemic approach. They focused on the creation of cooperation and knowledge exchange networks and ecosystems to enhance innovation capacities (including on non-technological matters), and on the upscaling of innovative solutions in industrial production systems and processes.

The Work Programmes showed a focus on the strengthening of capacity for innovation by supporting building blocks for technological R&D, taking an integrated approach to the key enabling and industrial technologies, and especially in the third Work Programme, promoting the convergence and cross-fertilisation effects in different innovation cycles and value chains. They aimed at fostering the uptake of

[46] The full description of the failures taxonomy is provided in 0 to this report.

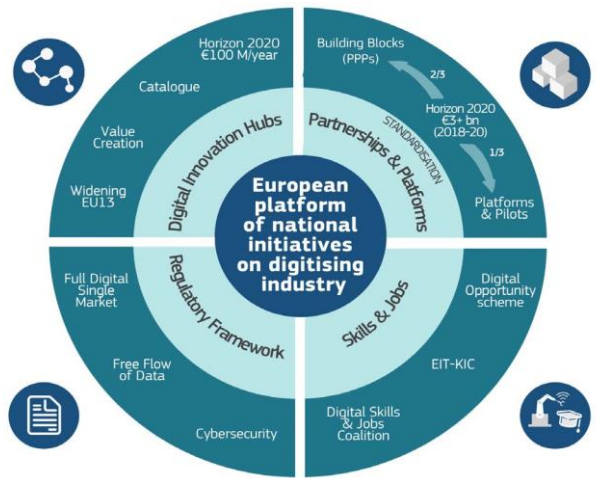
innovation by launching what is now called 'technology infrastructures'[47], allowing for technology and product validation under industrial conditions, controlled environments and/or real-life use cases across application fields. In other words, the focus was on lowering the risks of industry investments in R&D, to the benefit of both the intermediate and end users of the technological developments in multiple value chains. Technology infrastructures ranged from large-scale pilot lines and demonstrator projects, sector-specific or integrated cross-sectoral industry platforms to shared pilot facilities that allowed companies to cooperate with Research Organisations in their (local) ecosystems for the application of new disruptive capabilities to specific products, processes, or systems. Involving actors across the value chains, these activities also helped to ensure interoperability among the products developed, thus reducing fragmentation and setting the basis for de-facto standards.

The programmes also aimed at facilitating and fostering the diffusion of innovation by establishing Digital Innovation Hubs (DIH) and open testbed facilities across Europe for the small-scale piloting and testing of innovations. These facilities were also expected to allow for the creation of innovation ecosystems around competence centres and intermediaries who also provided non-technological support services to enhance innovation capacity.

Next to the public-private partnerships that already existed under FP7, new ones were created to support de-fragmentation of the research and industry communities in specific fields. Together with the ecosystems around the technology infrastructures, the partnerships were intended to offer a 'meeting place' for the creation of joint visions on roadmaps and priorities as well as improved understanding of user needs, supporting improved demand articulation. Combined with the close collaboration between the EC and the European Technology Platforms and industry associations, these 'knowledge value collectives'[48] were also charged with the task of forging close and lasting connections between the LEIT programming and stakeholder needs (we cover the relevance of the partnerships further in Section 4.2, below).

The growing cross-sectoral and interdisciplinary nature of the activities (encompassing ICT and NMBP technologies) as well as the increasing focus on 'place-based' innovation and stronger involvement of the Member States triggered the need for an overarching framework that could integrate and coordinate the multitude of initiatives, institutions and stakeholders involved in a common objective and vision. It led to the launch of the Digitising European Industry (DEI) initiative in 2016.

Figure 9 Pillars of the DEI initiative



Source: European Commission

The DEI strategy is an ambitious collective effort involving public and private stakeholders across Europe at regional, national and EU level. It constitutes a framework for actions allowing for the coordination of initiatives for digitising industry, co-investment to boost Europe's digital innovation capacities through Digital Innovation Hubs and public-private partnerships, prioritisation and intensified efforts towards standardisation, development of appropriate regulatory framework conditions, and the building of human capital ready for the digital transformation. The work is supported by high-level, EU-wide dialogue (roundtables) representing Member State initiatives, industry leaders, and social partners.

The programmes have therefore shown flexibility and responsiveness to the changing needs and developments during the FP. In the case of the LEIT ICT programme, Work Programmes show an increasing focus on supporting innovation across value chains and on the creation of ecosystems for

[47] The EC Staff Working Document 'Technology Infrastructures (SWD(2019) 158 final) defines Technology Infrastructures; as "facilities, equipment, capabilities and support services required to develop, test and upscale technology to advance from validation in a laboratory up to higher TRLs prior to competitive market entry. They can have public, semi-public or private status. Their users are mainly industrial players, including SMEs, which seek support to develop and integrate innovative technologies towards commercialisation of new products, processes and services, whilst ensuring feasibility and regulatory compliance".

[48] Defined as "networks of people in companies, universities, Research Organisations and elsewhere who work with a common set of knowledge". Source: Barry Bozeman and Juan Rogers, 'A churn model of scientific knowledge value: Internet researchers as a knowledge value collective,' Research Policy, (31), 2002, pp 769-794.

enhanced knowledge-sharing as well as uptake of innovation. The LEIT NMBP programme shifted its focus from an enabling technology (KET)-oriented perspective (e.g. individual nano-/bio-/advanced materials and production) towards a product-oriented perspective (KET-based products) where different materials and technologies might be applied. In this context, the field of nanotechnology was increasingly embedded under the umbrella of 'advanced materials', a trend that had started already under FP7.

The LEIT Space programme was mainly focused on the funding of collaborative research activities, using more traditional instruments for the creation of knowledge exchange and adoption of innovation. The programme responded to the objectives set out in the EU Space Strategy, focused on the potential role of the space sector to help address Europe's social, economic and strategic challenges. H2020 Space R&D activities have aimed to further support the development of Galileo and EGNOS programmes in both downstream and upstream sectors: R&D on downstream has supported the applications and the market uptake through all relevant sectors.

The programme has also likely benefited from the EU coordination procedure between the ESA, EDA and European Commission. The procedure aimed at identifying S&T needs for Space and, thus, to establish a list of urgent business needs to be addressed. In such a fast-changing industrial landscape as the one characterising the space sector, these kinds of coordination activities are key to ensuring alignment between the funding opportunities offered and stakeholder needs.

The LEIT programmes addressed the S&T and socio-economic challenges also through the targeted research that was funded. Reflecting their objectives (see Section 2.1.2, above), they supported technological developments as a basis for innovation across multiple sectors and in a wide variety of processes, goods, and services, while also responding to key societal objectives.

The Work Programmes show that the intervention areas focused on creating research results to benefit industry growth and competitiveness – in terms of reduced costs or faster production lines (e.g. research in the fields of micro-nano electronics and robotics), innovativeness reflecting global growth trends (e.g. artificial intelligence and advanced manufacturing), trustworthy IT systems (e.g. cybersecurity), innovative applications in downstream user sectors (e.g. artificial intelligence, IoT, and earth observation), and/or safeguarding space infrastructure.

The research activities also aimed at delivering results that would support EU industry in its 'societal mission' of adopting sustainable, environment-friendly products and services enhancing energy and resource efficiency (e.g. big data and advanced materials), human-centred processes (e.g. robotics), and 'safe-by-design' or 'ethics-by-design' products and services (artificial intelligence, nano-electronics), as well as ensuring trustworthy connectivity (e.g. next-generation internet). In addition, research was funded to mitigate or reduce the adverse effects of technology such as the energy consumption of microelectronics and advanced computing, and reducing e-waste and its environmental impact.

In this case, the flexibility and responsiveness to the changing needs and developments during the FP were for all LEIT programmes apparent in the shift in focus from a challenge-based perspective in the first half of H2020 – with industrial competitiveness and job growth as main targets – to an impact-based perspective in the second half of H2020 and, especially, the third Work Programme. In this context, the **'Digitising and transforming European industry and services'** focus area, which was highly influenced by the DEI, focused on two main strands of activity: support for SMEs to experiment with leading digital technologies through coaching, onsite implementation, demonstrators, etc. (i.e. the services provided in the DIH and Open Access Testbeds); and the further development and integration of new technologies into digital industrial platforms. This was to be done through partnerships focusing on agriculture (e.g. precision farming and digital rural communities), advanced manufacturing (connected smart factories), health (smart hospital of the future), and mobility and energy (smart grid and big data solutions for energy). The Focus Area predominantly funded projects concerned with automation, artificial intelligence and machine learning, as well as earth observation.[49]

In sum, while the primary objective was to enhance industrial competitiveness through an accelerated uptake of innovation and stronger absorption capacity, the technological focus was oriented towards areas of high societal relevance.

[49] European Commission (2021) Opportunities and Challenges in Targeted Funding of Research and Innovation: Lessons learnt from the Horizon2020 Focus Areas and implications for Horizon Europe Missions, CWTS, Technopolis Group.

Emerging trends

Studies and interviewees for the current review agree that convergence of technologies is a breakthrough factor for future technological, economic, and societal development. In this context, fast-developing technologies range from a variety of digital technologies (such as 3D printing, IoT, and advanced robotics) and new materials (bio- and nano-based) to new processes (e.g. data-driven production, artificial intelligence, and synthetic biology).[50]

In terms of priority-setting, studies and high-level panels indicate the (ongoing) importance of KETs such as advanced manufacturing technologies, advanced materials and nanotechnologies, micro-/nano-electronics and photonics, to which the High-Level Strategy Group for Industrial Technologies recently proposed to add artificial intelligence as well as security and connectivity. A 2019 horizon-scanning workshop bringing together directors of research and technology organisations and funding bodies from 18 European countries, added to this list a range of non-ICT technologies that the experts considered as having strong potential. These included human-machine interaction, smart farming, smart nanomaterials, and additive manufacturing.[51] The LEIT Work Programmes show that all these technologies have been covered in the programmes' activities.

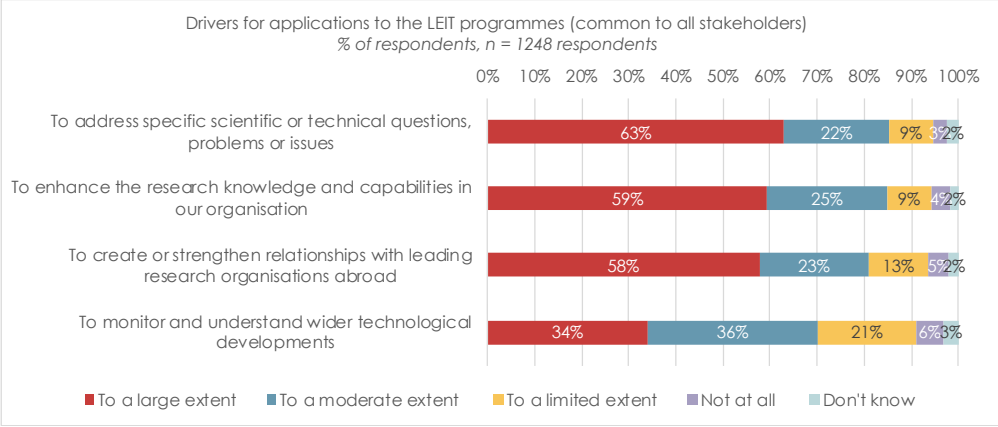
4.1.2. Alignment with the stakeholder needs

The directions set in the LEIT programmes are based on input from a broad range of sources, encompassing the studies informing the overarching EU priorities and Framework Programme, opinions of high-level expert and advisory groups, stakeholder associations and fora such as the partnerships, strategic intelligence studies, foresight and forecast exercises (including horizon scanning), and finally, open stakeholder consultations.

The opinions of the stakeholders consulted in the context of this study broadly confirmed the relevance of the directions set in the ICT and Space LEIT programmes, public and private stakeholders in the field overall agree that while building on the achievements of FP7, the Space programme improved its relevance by focusing on (inter alia) EU competitiveness, the development of services and applications, and activities related to addressing interdependencies and autonomy.

Survey respondents also indicated a good alignment between the instruments that the LEIT programmes adopted and the drivers of participation in the programme activities. For all stakeholders (research and industry alike), the motivation for their applications centred around technology development geared towards industrialisation and the creation of sustainable collaborations or networking effects. The lower importance given to the understanding of wider technological developments indicated an alignment of their needs with the pronounced focus on innovation under H2020. There were no major differences in responses between the stakeholders active in the different LEIT programmes.

Figure 10 Drivers of participation in the LEIT programmes



Source: Technopolis Group, stakeholder survey

[50] EC (2018) Re-Finding Industry – Defining Innovation, Report of the independent High Level Group on industrial technologies, European Commission, DG RTD.
[51] Müller, J., Potters, L. (2019) Future technology for prosperity: Horizon scanning by Europe's technology leaders, Workshop report. The Research Council of Norway, European Commission.

4.1.3. Relevance related to the positioning of the European Union

The preceding sections in this chapter clearly show that H2020 and its LEIT programme part addressed the issues needed to speed up Europe's recovery from the 2008/2009 and 2012 economic crises – both in terms of objective (de-industrialisation and digitalisation of EU industry, while providing support to address societal challenges) and in terms of the activities aimed at overcoming the key failures in the EU R&I ecosystems.

The KETs provide the basis for innovation in a range of products across all industrial sectors. They are known to drive the development of entirely new industries and they are instrumental in modernising Europe's industrial base, as well as underpinning the shift towards a smart, fair, and sustainable economy. From a technological perspective, all critical technologies – both established and fast-developing ones – were covered. The analysis reported below confirms the importance of ongoing focus on the development and exploitation of these technologies' potential for Europe – and in some cases even the critical importance to safeguard Europe's competitiveness. On one hand, depending on the technologies being discussed, the US and China are both considered competitors in terms of scientific excellence and/or patenting activity. On the other hand, our reporting also suggests the potential relevance of international collaboration under the FP with research or industry organisations based in non-EU countries. Reflecting the recommendations of the High-Level Strategy Group for Industrial Technologies, the DEI Working Group on Future Partnerships recommended to continue investing in the development of technologies no matter the position on the global market. It considered: "Only being excellent in innovation makes it more likely to keep manufacturing within Europe. This ranges from very early and basic research up to more applied research."[52]

Positioning of the Union from an S&T perspective

Recent bibliometrics data[53] confirms the high degree of **EU scientific excellence**[54] also in the field of KETs. Europe globally performed well for all KET priorities[55] and it increased its scientific impact in the fields of electronics, manufacturing, materials, nanotechnology, and photonics. However, Australia, Canada, and the United States are still the global leaders and China is catching up on the EU27 in all KET priorities (except biotechnology) and has overtaken the EU27 on citation impact in the field of materials and nanotechnology.

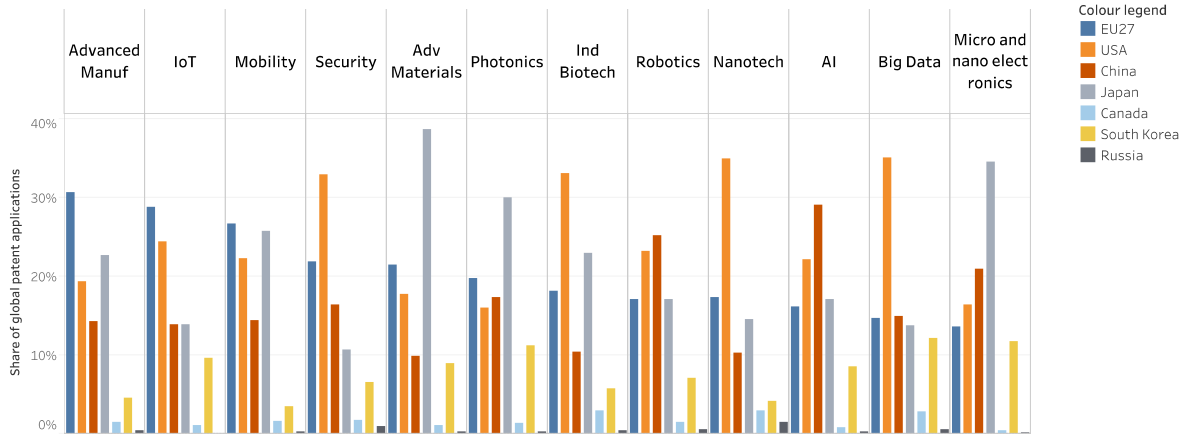
According to a 2020 EC Working Paper,[56] in 2016 the EU28 was leader in scientific excellence in the new KET field of artificial intelligence. China registered a remarkable increase, doubling its relative weight in just a decade, and has been emerging quickly also as the global leader in scientific production in the AI domain. The Paper found that the EU trails behind the US and China also when it comes to AI innovation performance (i.e. number of firms active in AI).

A recent Advanced Technologies for Industry (ATI) study,[57]looking into technology trends and adoption, notes that, in terms of **patent applications**, the EU27 holds the highest share of worldwide patent applications in advanced manufacturing technologies, followed by Japan and the US, and has a leading position in the internet of things (Figure 11). It has a high share of digital technologies for mobility, on par with Japan, and has an average share in robotics, nanotechnology, industrial biotechnology, photonics and advanced materials (between 17% and 21%), and lower shares in micro- and nanoelectronics, big data, and artificial intelligence.

In terms of the other economies, the US has a leading position in the fields of security, industrial biotech, nanotech, and big data. China excels in the fields of AI and robotics, where it is global leader, and Japan excels in advanced materials, photonics, and micro-nanoelectronics. Other comparable countries performed below the EU27 average in terms of patenting.

[52] Digitising European Industry Working Group on Future Partnerships, Report Version 1.0 March 2018.
[53] Science-Metrix, PPMI (2021) Provision and analysis of key indicators in research and innovation – Final Study Report covering Work Packages 1-6, European Commission, Directorate-General for Research and Innovation.
[54] Measured in terms of scientific impact.
[55] The study covered the KETs defined as Biotechnology, Electronics, Manufacturing, Materials, Nanotechnology, and Photonics.
[56] Correia, A., Reyes, I. (2020) AI research and innovation: Europe paving its own way, R&I Paper Series, Working Papers 2020/15, European Commission, DG R&I.
[57] Izsak, K., et al. (2021) Advanced Technologies for Industry – Final Report, Report on technology trends and technology adoption, Technopolis Group, IDC, Fraunhofer ISI, IDEA Consult. A study for the European Commission, European Innovation Council and SMEs Executive Agency (EISMEA).

Figure 11 **Share of global patent applications in the EU27 and competing economies in 2018 (last available year with complete patent data)**



Source: ATI (2021), Fraunhofer ISI calculations based on EPO Worldwide Patent Statistical Database (PATSTAT)

4.2. Relevance of the partnerships

As outlined in the Evaluation Study on the relevance and internal coherence of Horizon 2020 and its policy mix[58], public-private partnerships (PPPs, encompassing co-programmed PPPs and Joint Undertakings (JUs)) and public-to-public partnerships (P2P) have been set up as key mechanisms to deliver the European Research Area (ERA) policy. A key notion in the ERA intervention logic is that more coordinated implementation of national and European R&I programmes would allow for better flows of knowledge, technology, and people. The H2020 Regulation sets the rationale for PPPs and P2Ps in the context of the effort and investment required for R&I to contribute to Europe's wider competitiveness goals and helps in tackling major societal challenges. These 'linkage instruments' aim to ensure that the implementation of H2020 responds to the evolving opportunities and needs of science and technology, industry, policies, and society. Partnerships have now become responsible for the implementation of large parts of the H2020 programme, including in LEIT.

4.2.1. Alignment with S&T and socio-economic developments

As detailed in Annex II to this report (separate document), the Strategic Research Agendas (SRIAs) of the partnerships under LEIT were closely aligned with the relevant strategic objectives and socio-economic challenges and needs to be addressed in their respective fields. The partnerships in the LEIT programme are also well embedded into the overall EU policy agenda.

The key rationale for both P2Ps and PPPs is to foster integration and long-term collaborations, thereby addressing **systemic failures.**[59] This is especially the case for the cPPPs and JUs in the LEIT programme part, which both aim to address the insufficient collaboration between system actors and poorly integrated value chains. ERA-NETs also aim to stimulate collaboration between Member States and ensure the proper functioning of innovative cycles. EIT KICs have the goal of interlinking research activities, industry needs and higher education curricula. All types of partnerships are also set up to strengthen knowledge and innovation absorption and address shortages of skills. The PPPs and P2Ps under LEIT equally aim at developing and maintaining R&I infrastructures and bearing their associated high fixed costs. Some of the partnerships are expected to play an important role in supporting strategic international cooperation initiatives and standards.

4.2.2. Alignment with stakeholders' needs

The activities of PPPs are based on SRIAs co-developed by the different partners involved. They therefore foster the development of shared visions on the goal and **direction** of the required system transformation process. Even more so than in other parts of the Work Programme, the evidence collected shows that they address the needs of stakeholders across entire value chains and aim at

[58] Daimer S., Seus S., Afghani N., Wang A., Kroll H., Howoldt A., (2022) Evaluation Study on the relevance and internal coherence of Horizon 2020 and its policy mix. Interim report 2. Fraunhofer Institute for Systems and Innovation Research ISI, Technopolis Group, Austrian Institute of Technology, 4front. (upcoming – not published).
[59] European Commission, 'A new ERA' report on the Partnerships/Horizon Europe.

building, strengthening, and expanding the European ecosystems in their areas of intervention (more details in Annex II – Partnership Reports). In principle, this makes them rather well-suited instruments to address **transformational failures**, and in particular directionality failures[60]. Public-private partnerships, especially cPPPs, also increasingly aim at anticipating users' needs to improve technology diffusion and uptake by end-users. Closely connected to the ERA objectives, partnerships also aim at enabling multi-level policy coordination, which is especially a key target for P2Ps. They are indeed set up to foster stronger alignment and integration of European, national and regional R&I policies, funding programmes and investments. They are regarded as having a bridging function between the regional or national and EU level, R&I communities and funding agencies, academic and non-academic stakeholders, and finally linking to third countries, where possible. An optimal alignment of the scope and contents of the activities in the ERA-NETs with other instruments and initiatives is therefore critical.

4.2.3. Alignment with needs related to EU competitive positioning

Building critical mass and encouraging a more competitive European industry are also two key objectives of the ERA policy agenda, and partnerships are well-suited to deliver on these elements. Partnerships are also well-suited to foster the absorption of innovation and address the low level of investment in R&I, both public and private. This is especially the case through mechanisms to share investment risks in the development and deployment of some (still immature) technologies, thereby addressing information asymmetries. The evidence collected and analysed in Annex II shows that the technology areas upon which the LEIT Partnerships focus are diverse in terms of EU performance compared to global competitors, technology uptake capacity by the market, and availability of professionals with technological skills in that area. This affects the function that these partnerships have in their specific R&I ecosystems.

5. Efficiency

In this chapter we summarise our findings related to the evaluation criterion of efficiency and the topics of investigation under each evaluation question. In Section 5.1 we cover the efficiency of the implementation processes. Section 5.2 reports on cost-effectiveness.

The data and analyses relate to the LEIT programme part only. Basic figures on the budget distribution and stakeholder participation are also provided in the state of play description in Section 5.1. The full analysis, including the details on the survey responses, is provided in Annex VI of this report (separate document).

5.1. Efficiency of the implementation processes

The programme implementation processes assessed in this section encompass the EC administration and management processes (Section 5.1.1), the project application and selection procedures, including the time-to-grant (Section 5.1.2), the funding distribution and success rates (Section 5.1.3), the funding distribution over the stakeholders (Section 5.1.4), the management and monitoring procedures (Section 5.1.5), and the information, communication and valorisation processes (Section 5.1.6).

It should be noted that the assessment of the EC efficiency in programme implementation[61] and the adequacy of the human resources for a quality implementation was hindered by the lack of data on the EC operating costs at the programme part level, both financially and in terms of human resources. The difficulty to distinguish between programme implementation and policy-related tasks carried out by the individual EC officials is a major barrier in this context.

5.1.1. EC administration and management procedures

Delegation of the programme management implementation

With H2020, new management modes became more prevalent and the delegation of the programme management to Executive Agencies (EAs) for some programme parts became fully effective. According to the H2020 Interim Evaluation, Horizon 2020's efficiency was positively influenced overall by the

[60] Weber, K. M., & Rohracher, H. (2012). Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework. Research Policy, 41(6), 1037-1047.

[61] In the international practice, the operational cost efficiency of R&I funding agencies is assessed by calculating all operational costs versus the funding provided, and/or by setting the number of proposals managed against the FTE of Human Resources.

extensive delegation of the programme implementation. Related to the LEIT programme part, we can estimate that about **50% of projects and 25% of the overall budget** was delegated to EAs and other entities (by means of specific grant agreements).

Next to the delegation of the programme implementation to the Executive Agencies, the growing importance under H2020 of the cascade funding model (financial support to third parties – FSTP) is to be noted. In its 2018 report[62] the European Court of Auditors considered that this mechanism shifts the administrative burden from the EC to the beneficiary responsible for managing the calls for sub-grants. This funding model (piloted under FP7) was at the core of the services provided by the Digital Innovation Hubs and testbeds. It is also increasingly used in other R&I projects, in combination with the traditional grant model. An important limit to this funding mechanism, however, is the lack of a centralised data management system for the model, including the overall budget, profile and geographical location of the beneficiaries, and benefits deriving from the support received. The capacity to assess the effectiveness of this funding mechanism and its value for the achievement of the FP objectives is therefore highly limited.

Overall, the adoption of these new programme management modalities creates challenges in terms of policy coordination, such as bridging the gap between knowledge creation in FP projects and the use of this knowledge in the strategic programming and policy processes. The Evaluation Study on the internal coherence and relevance of H2020 and its policy mix[63] underlined the difficulty in establishing new interaction processes between the EAs and Commission services that lead to policy-relevant recommendations beyond individual project results or small clusters of projects. They also imply the need for more resource investment in multi-level coordination – both internally between the EC and EAs and with public and private partners.

Simplification of financial rules

Simplifications introduced under H2020 aimed to reduce the complexity of the cost-eligibility rules and processes, thereby contributing to lowering the financial error rate and increasing the legal certainty for beneficiaries as well as the attractiveness for new beneficiaries, especially smaller entities like SMEs. In general, the lack of legal certainty on cost eligibility constitutes an important risk for beneficiaries, especially for newcomers and SMEs.

Stakeholders highly valued these simplification measures. They appreciated the clarity of the H2020 funding schemes and considered them to be adequate for their organisation's needs. Most survey respondents (60%) also considered H2020 simplifications related to budget and financial rules to be a significant improvement compared to FP7. However, they saw room for improvement in the worktime recording (58%) and the personnel cost calculation rules (52%), and considered that the rules on reimbursement of internally invoiced goods and services could be further simplified (38%).

5.1.2. Project application and selection processes

Proposal writing requires a significant effort in terms of time and cost.[64] Much of the time burden is clearly on the project coordinators – and linked to the requested budget size of the proposals. The rather low success rates in the LEIT programme part explained why more than half of the survey respondents considered the efforts required not to be proportionate to the low chances of receiving funds. However, about 60% of survey respondents considered the proposal writing efforts to be proportionate to the complexity of the proposed project, the number of partners involved, and the strategic relevance to the research topic.

The simplification measures implemented under H2020 were intended to alleviate the burden on the applicants in the **proposal submission process**. Overall, survey respondents confirmed the findings of the H2020 Interim Evaluation, and about half of them considered the simplification measures for the proposal submission processes to have been effective. Specifically, they positively assessed the Work Programmes (65%), the Annotated Grant Agreement (about 60%), and the Online Manual (about 55%). They also appreciated the quality of the EC communication activities and the clarity of the programme announcements and calls, the description of the aims and objectives of the calls, and the administrative

[62] European Court of Auditors, Special Report: The majority of simplification measures brought into Horizon 2020 have made life easier for beneficiaries, but opportunities to improve still exist, 2018.
[63] Daimer S., Seus S., Afghani N. Wang A., Kroll H., Howoldt A., (2022) Evaluation Study on the relevance and internal coherence of Horizon 2020 and its policy mix. Interim report 2. Fraunhofer Institute for Systems and Innovation Research ISI, Technopolis Group, Austrian Institute of Technology, 4front. (upcoming – not published)
[64] About 40% of survey respondents indicated that more than 30 person-days were needed, 25% of respondents needed between 20 and 30 person-days.

requirements. They saw room for further improvement in the functioning of the Participants Portal, Horizon 2020 Helpdesk, and most importantly, the proposal template. Most criticised were the overall user-friendliness of the template, the page limit (70 pages), and its frequent updates. Survey respondents saw a need for improvement also in relation to the clarity of the request for ethical review.

Reflecting the long-established processes at most R&I funding organisations internationally, the EU Framework Programmes uses a standard panel review approach for **the evaluations**. Survey respondents highly regarded the proposal evaluation process in terms of the clarity of the information and the description of the award criteria in the Work Programmes, and the fairness of the evaluation. Close to half of them also considered that the two-stage proposal process substantially improved the efficiency of the proposal submissions. Transparency of the funding decisions and completeness of the evaluation reports, however, remained problematic. These findings confirmed an assessment made in the 2017 European Implementation Assessment by the EPRS[65], the concerns noted in the H2020 Interim Evaluation about the quality of evaluation feedback, which closely relate to the request for more transparency on the funding decisions.

The timeliness of the project application and selection process (i.e. TTG) significantly improved compared to FP7 and since the Interim Evaluation of H2020. Survey respondents perceived it as the main area of improvement in the H2020 implementation compared to FP7. For the LEIT programme part, on average, and across the three programme parts, the time-to-grant was of **183 days** – an overall performance better than the quality standard of maximum 245 days set in the FP legal base.[66]

These figures are, however, highly influenced by the SME Instrument which had a specific time-to-grant target of 3 to 6 months, depending on the phase. Excluding the SME Instrument, the average time to grant for the LEIT programme part overall was 216 days. The quality standard set for H2020 was therefore broadly met for the LEIT programmes (except for the Space part). Important improvements compared to FP7 can be seen in all three LEIT programmes – in this case including the LEIT Space programme.

Table 6 Average time-to-grant in the LEIT programmes

	FP7 Average time-to-grant 2007-2013 (in days)	H2020 Average time-to-grant 2014-2020 (in days)	H2020 Average time-to-grant 2014-2020 (in days) excl. SME Instrument
ICT	259	183	217
NMBP	329	163	190
Space	399	220	257
Overall	**n.a.**	**183**	**216**

Source: Technopolis Group, based on CORDA data (15/11/2021); Seventh FP7 Monitoring Report, 2015

5.1.3. Funding distribution over action types and instruments and success rates

As mentioned in Section 3.2, above, the LEIT programme part funded **3,161 projects** for an EU contribution of in total **€10.3bn**. In this section we cover the findings on the funding distribution over action types and instruments and the average project size, including the trends over time. The final sub-section is dedicated to the analysis of the success rates.

Funding distribution over action types

The Research and Innovation Actions (RIA) accounted for about 50% of the funding, while Innovation Actions (IA) made up about 40%. Coordination and Support Actions (CSA) and the SME Instrument accounted for about 5% of the budget, each.

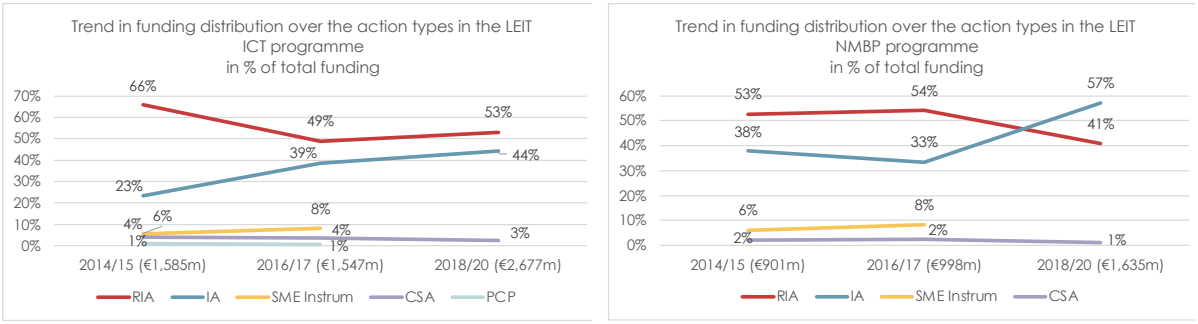
Over time, we noted an ongoing decrease in the funding of RIAs (typically at TRL 4/5) in the LEIT programme part overall, and a corresponding increase in the funding of Innovation Actions. While in WP2014-2015, RIA projects accounted for close to 60% of the budget, in WP2018-2020 their funding

[65] EPRS, EU (2017), Horizon 2020 EU framework programme for research and innovation – European Implementation Assessment, February 2017.
[66] Details for all LEIT programmes and intervention areas are provided in Annex VI to this report (separate document).

share declined to 50%. This trend is visible especially in the LEIT ICT programme (as of the WP2016-2017) and in the LEIT NMBP programme, where it implied a clear shift in funding priority in the WP2018-2020 (Figure 12).

These findings reflect the concerns raised in the Interim Evaluation of H2020, which highlighted the apparent trend of diminishing funds in H2020 for lower TRLs (2-4), especially in the case of ICT and NMBP. They also support the findings in the Evaluation Study on the relevance and internal coherence of H2020[67] which stated that while efforts were made to address these concerns,[68] the funding continued to be focused on closer-to-the-market activities such as prototyping, testing, demonstrating, piloting, and scaling-up.

Figure 12 Distribution of funding over action types in the LEIT ICT and NMBP programmes between 2014 and 2020



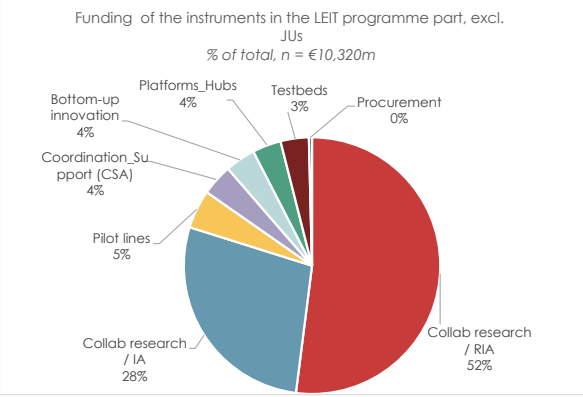
Notes: Excluding the JUs
Source: Technopolis Group, based on CORDA (15/11/2021)

Funding distribution over the instruments

A specific characteristic of the H2020 Framework Programme was its use of funding instruments beyond the 'standard' collaborative research and cooperation/support measures. H2020 expanded the policy mix with a set of 'demand-side innovation' instruments, including the (bottom-up innovation) SME Instrument and public procurement measures, and under the LEIT ICT and NMBP programmes, instruments providing access to technology infrastructures, i.e. pilot lines, platforms/hubs, and testbeds.

Overall, the LEIT programme part dedicated about 50% of its budget to the funding of 'standard' collaborative RIA projects and about 30% to the 'standard' collaborative IA ones ().

Figure 13 Funding of instruments in the LEIT programme part



Source: Technopolis Group, based on CORDA data (15/11/2021)

The demand-side innovation instruments accounted for 16% of the LEIT programme part budget, fairly evenly spread over the pilot lines, the bottom-up innovation SME Instrument[69], the platforms, hubs, and testbeds.

Around 10% of the overall LEIT programme part budget was therefore dedicated to the funding of access to technology infrastructures (platforms/hubs, pilots, and testbeds) – specifically, 11% of the LEIT ICT programme budget and 16% of the LEIT NMBP funding.

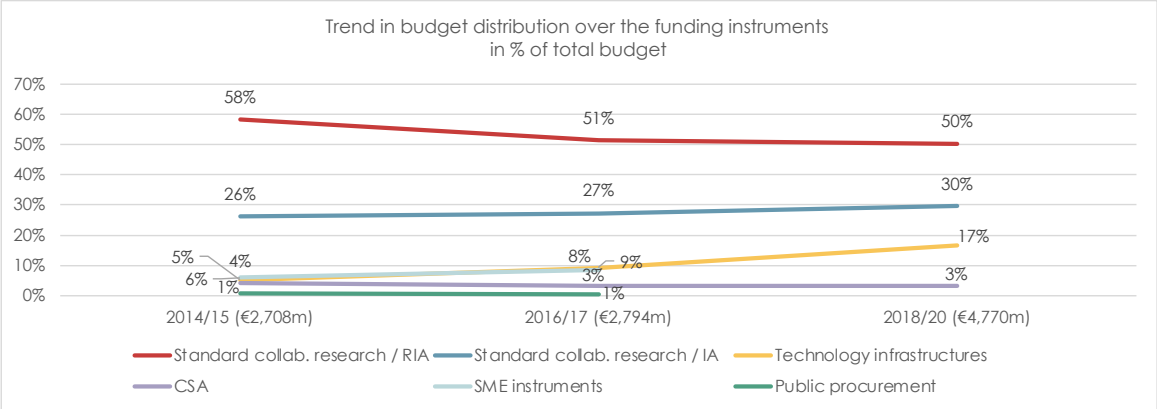
[67] Daimer S., Seus S., Afghani N. Wang A., Kroll H., Howoldt A., Evaluation Study on the relevance and internal coherence of Horizon 2020 and its policy mix. Interim report 2. Fraunhofer Institute for Systems and Innovation Research ISI, Technopolis Group, Austrian Institute of Technology, 4front. (Second Interim Report – LEIT case study – not published).

[68] The third WP for ICT included a call related to cyber-physical systems of systems (ICT-01-2019), which addressed TRLs 2-5. In the case of NMBP, the third call demonstrated a clear emphasis on TRLs 3-5 in medical technology solutions (compared to levels 4-7 in the first WP) and biotechnology continued to focus on TRLs 3-6.

[69] The SME Instruments were funded under the LEIT programmes Up to the 2016/2017 WP. For the last funding period, the SME Instruments were funded under the EIC Pilot and therefore no longer included in the LEIT programme part.

Over time, there was a considerable increase in budget share of the technology infrastructure instruments: from 5% in 2014-2015 to close to 20% in 2018-2020 (Figure 14). This was accompanied by an ongoing decrease in the funding of the 'standard' collaborative RIA projects in the LEIT programme part (from about 60% in WP2014-2015 to 50% in WP2018-2020), next to the discontinuation of the SME Instrument funding under the LEIT programme part in 2018-2020. The drop in the funding share of 'standard' collaborative RIA projects was especially pronounced in the LEIT ICT programme (from 66% in 2014-2015 to 53% in 2018-2020).

Figure 14 Distribution of the funding over action types and instruments over time



Source: Technopolis Group, based on CORDA data (15/11/2021)

Average project budget and size

The H2020 LEIT programme part shows an average **project budget of €3.3m** and, on average, **8.8 partners per project**. Under FP7, these figures were slightly higher: an average of €3.5m for the project budgets and 10.4 partners per project. A robust comparison of H2020 data with FP7, however, needs to consider the influence of the SME Instrument which were introduced under H2020. These mono-beneficiary projects accounted for 32% of the total projects funded (1,052 projects) and had a particularly low budget (€0.4m on average). When excluding the SME Instrument (as well as the Public Procurement projects), the 'comparative' data for H2020 show a €4.7m average EU contribution per project and project consortia with on average 12.7 partners, thus higher compared to FP7 against both dimensions. Differences can be noted between the LEIT programmes, with the LEIT NMBP showing the highest 'comparative' average project budget and size (€6.3m and 15.8 partners), followed by LEIT ICT (€4.6m and 12.4 partners on average), and the LEIT Space showing the lowest figures (€2.7m and 9 partners).

The choice of instruments used was significant in explaining these differences. Pilot lines, platforms/hubs, and testbeds have particularly high average budgets and numbers of partners involved, ranging from €8m to €12m and from 22 to 26 partners on average. The 'standard' collaborative research RIA and IA projects, instead, had an average budget of around €5m and a project size of between 12 and 13 partners, slightly higher than under FP7.

Large-scale/high-cost projects were mostly funded under the LEIT ICT and NMBP programmes. For both programmes, data shows an overall increase in average project budget and size over time, which implied an increasing concentration of the budget available. In the LEIT Space programme, instead, the budget was thinly distributed over a relatively high number of projects with a rather limited budget per project (between €2m and €3m).

Success rates

The overall **success rate for the LEIT programme part was 9%.** Out of 33,868 proposals, 3,153 were successful and funded. Overall and for the three LEIT programmes, the success rates were lower than under FP7 (Table 7).

Also in this case, however, one should take account of the influence of the SME Instrument, which showed a particularly low success rate (6%). For the other instruments, success rates ranged from 18% for the testbeds and 16% for the 'standard' Innovation Actions to 13% for the Platforms/Hubs and 11% for the pilot lines and 'standard' RIAs. As shown in the table below, the LEIT programme part had a 'comparative' success rate of 15%, only slightly lower than the 17% under FP7.

Data on the shares of high-quality proposals that reached funding and the rates of (eligible) proposals with scores below threshold shed light on (some of) the underlying causes. The high rate of proposals with scores below threshold in the LEIT ICT and NMBP programmes suggests an issue with the capacity of the community to respond to the expectations set in the calls.[70] The particularly low success rate of high-quality proposals (i.e. proposals scoring above threshold and receiving funding) in the LEIT ICT programme (and for the LEIT Space programme when not considering the SME Instrument) suggests an underfunding compared to the interest and needs of stakeholders.

Table 7 Funding success rates

	FP7	H2020			H2020 without SME Instrument		
	Success rate	Success rate	Rate of proposals with scores below threshold	Success rate of high-quality proposals	Success rate	Rate of proposals with scores below threshold	Success rate of high-quality proposals
ICT	15%	9%	64%	24%	14%	46%	25%
NMBP	30%	8%	75%	34%	11%	80%	56%
Space	26%	18%	42%	31%	20%	30%	28%
Overall	**17%**	**9%**	**66%**	**27%**	**15%**	**55%**	**30%**

Source: Technopolis Group, based on CORDA data; For FP7: EC, Ex-Post-Evaluation of the 7th EU Framework Programme (2007-2013)[71]

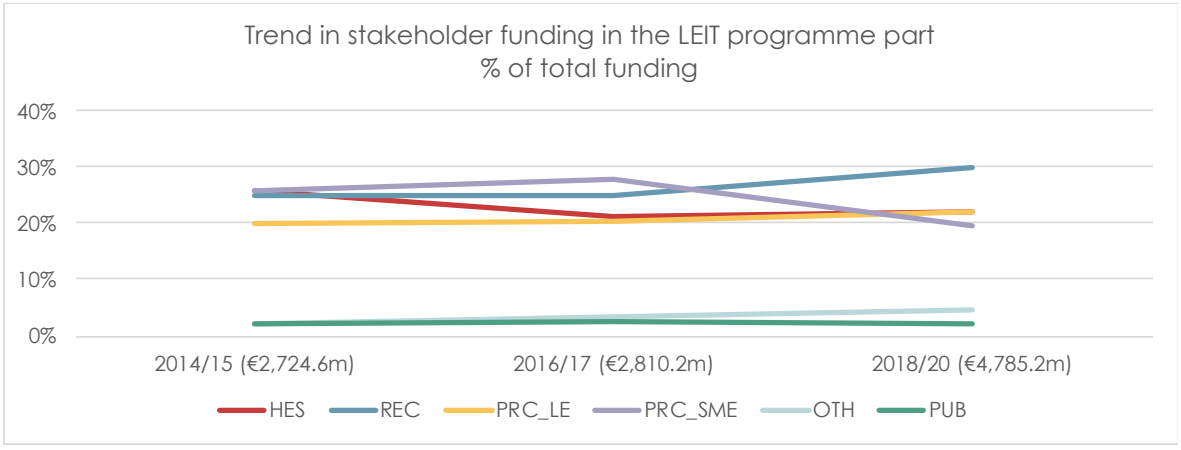
5.1.4. Funding distribution over the stakeholders

The state-of-play analysis (see Section 3.2, above) showed that Research Organisations were the main beneficiaries of the LEIT programme part funding, accounting for about 30% of the budget or €2,793m. They were closely followed by the three other main stakeholder groups (Higher Education Institutions, SMEs and Large Enterprises) that had a close to equal funding share between 21% and 23%.

Trend in funding distribution

Over time there was a **change in the LEIT stakeholder composition**: i.e. an increase in the funding share of the Research Organisations (from 25% of the funding in WP2014-2015 to 30% in WP2018-2020) and a decrease in the funding of Higher Education Institutions and SMEs (in both cases, from about 25% in WP2014-2015 to 20% in WP2018-2020) (Figure 15).

Figure 15 Trend in stakeholder funding



Source: Technopolis Group, based on CORDA data (15/11/2021)

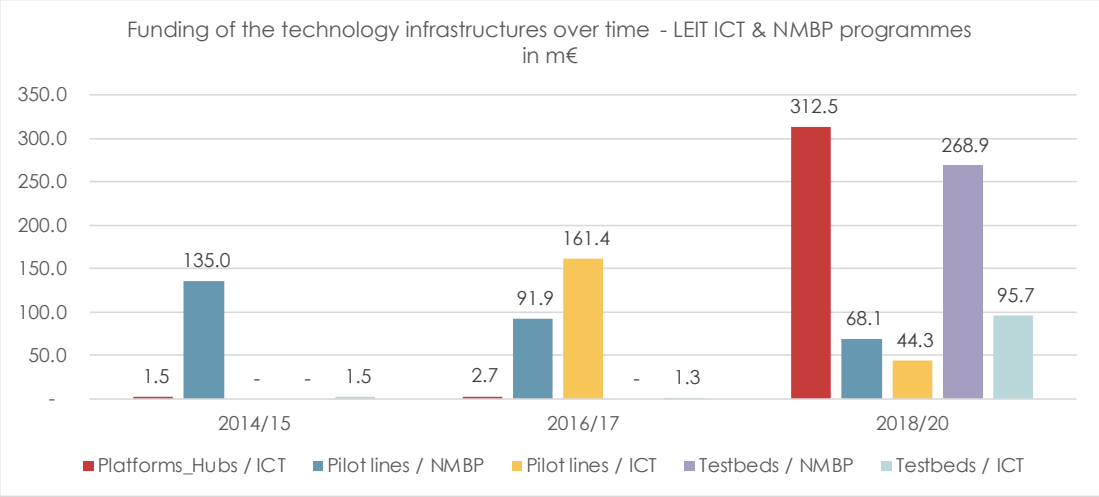
This trend can be explained by the patterns in the stakeholders' participation in specific instruments, combined with the trends in the LEIT programme part funding of the instruments. As mentioned in

[70] Another factor mentioned by the EC in relation to the NMBP programme was the higher-than-average thresholds defined for some calls. Our analyses did not show major differences in shares of calls with high thresholds among the LEIT programmes.
[71] Fresco, L.O. et al (2015) Commitment and Coherence, essential ingredients for success in science and innovation – Ex-post evaluation of the 7th EU Framework Programme (2007-2013), European Commission.

Section 5.1.3, above, the major changes in the funding of the instruments over time were the discontinuation of the funding of the SME Instrument under the LEIT programme part in 2018-2020, the decrease in the funding of the 'standard' collaborative RIA projects, and the increase in budget share of the technology infrastructure instruments (platforms/hubs, pilots, and testbeds).

In the first two WPs, the funding of technology infrastructures focused on the pilot lines; in WP2018-2020 the focus was especially on platforms/hubs in the LEIT ICT and testbeds in the LEIT NMBP (€269m) (Figure 16).

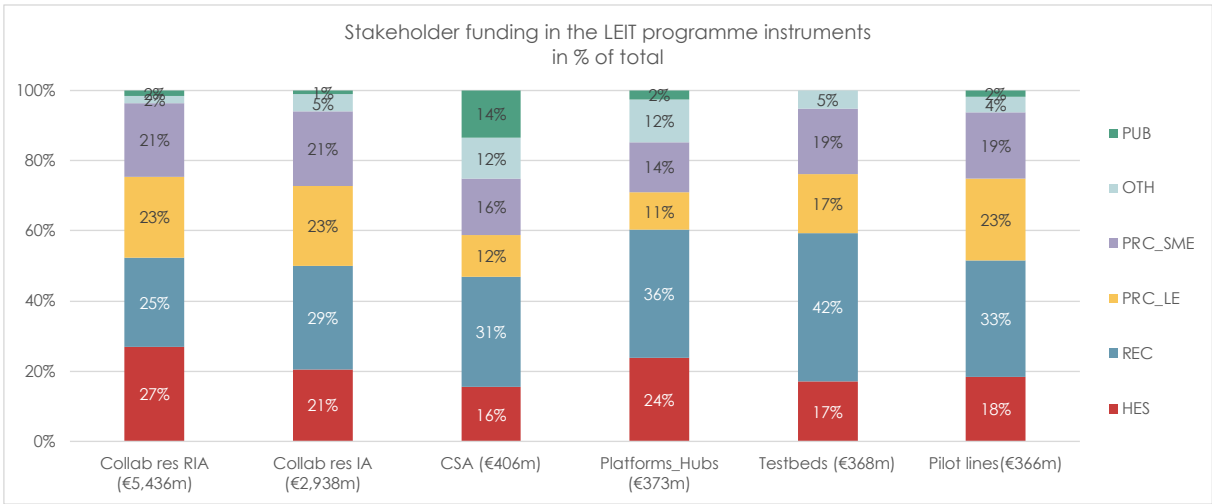
Figure 16 Budget allocated to the technology infrastructures over time



Source: Technopolis Group, based on CORDA data (15/11/2021)

Figure 17 shows the funding shares of the stakeholders in the instruments. Research Organisations were the main beneficiaries in all instruments except for the 'standard' collaborative RIA, but especially so in the platforms/hubs and testbeds where they accounted for about 40% of the funding. The increase in the funding of these technology infrastructures therefore benefitted especially these stakeholders. Higher Education Institutions, instead, were the main beneficiaries of the 'standard' collaborative RIA and accounted for (only) 17% of the funding for the testbeds. The trend in lower funding shares for the RIA and increasing shares for the testbeds inevitably implied lower funding shares for these stakeholders. The funding shares of the SMEs were (naturally) influenced by the discontinuation of the SME Instrument funding under the LEIT programmes. In addition, however, also their limited participation in platforms/hubs (compared to the 'standard' RIA and IA projects) played a role.

Figure 17 Distribution of the funding over the stakeholders in the funding instruments

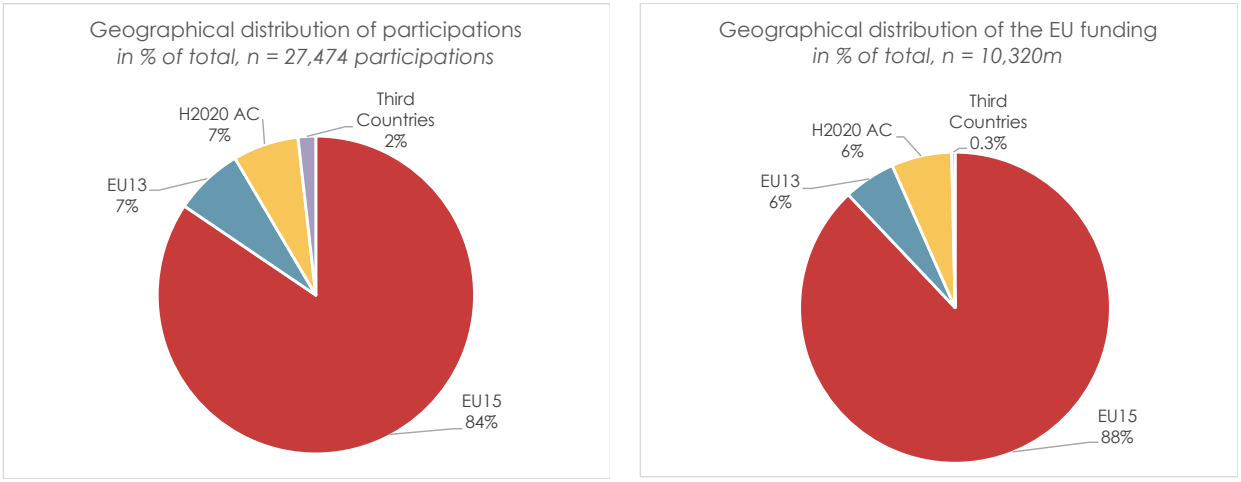


Source: Technopolis Group, based on CORDA data (15/11/2021)

Geographical distribution of the funding

In terms of geographical location of the LEIT participants, the former EU15 accounted for close to 90% of the funding and about 85% of the participations (Figure 18, below, left- and right-hand graphs, respectively). The EU13 MS and the H2020 Associated Countries accounted for around 7% of the funding and participations, each. Third Countries accounted for 2% of the participations and had a funding share of 0.3%.

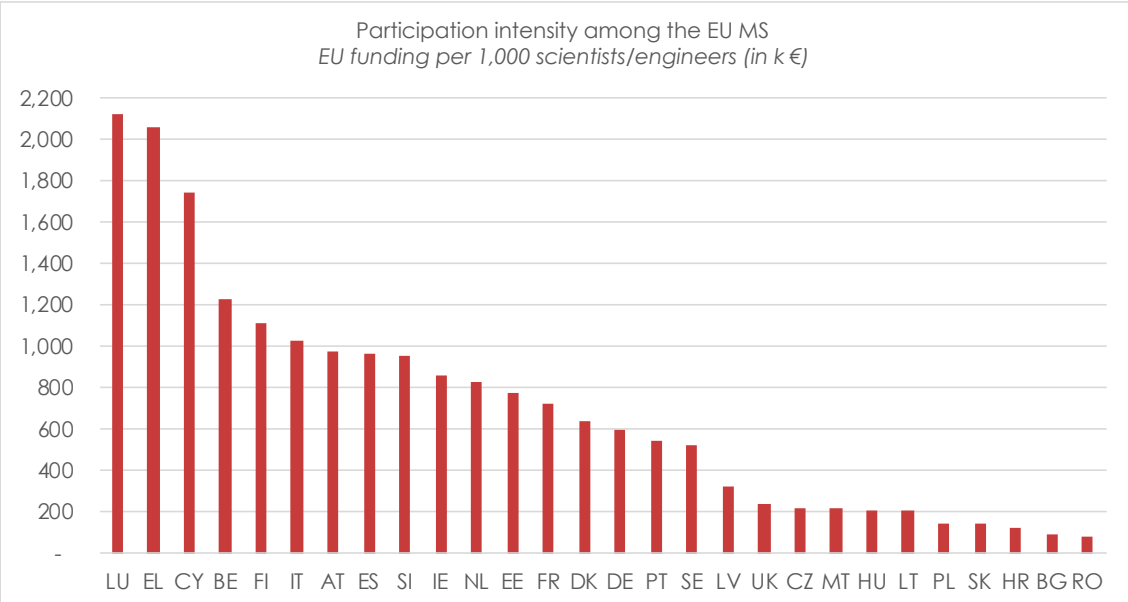
Figure 18 Geographical distribution of the funding



Source: Technopolis Group, based on CORDA data (15/11/2021)

Among the EU Member States, Germany accounted for the highest funding share (19%), followed by Spain (13%), France (13%), Italy (11%), and the UK (8%). Poland, Czech Republic, and Slovenia were the highest funded EU13 MS (2%, 1%, and 1%, respectively). However, in terms of participation intensity (i.e. the EU contribution in relation to the population of scientists and engineers in the country) Luxembourg, Greece, and Cyprus appear as the main beneficiaries (Figure 19). Slovenia ranked among the top ten EU Member States that benefited, while Estonia was ranked 12th, ahead of France, Denmark, and Germany. The ten EU MS that benefited least were predominantly EU13 countries.

Figure 19 Participation intensity among the EU MS



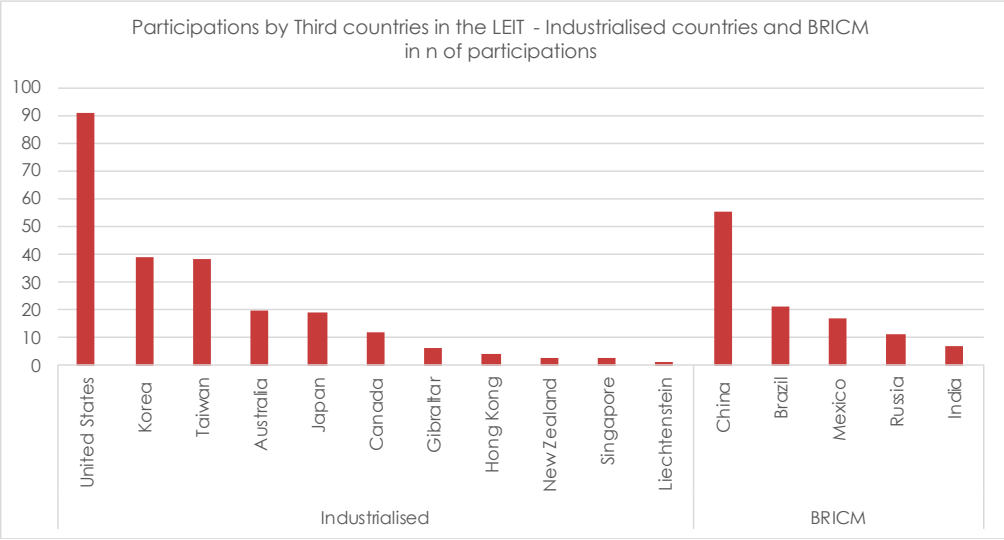
Notes: Population of scientists/engineers is based on Eurostat 'HRST by category, sex and age [hrst_st_ncat]' data for 2018; data exclude the JU, P2Ps and EIT KICs.
Source: Technopolis Group, based on CORDA data (15/11/2021)

Funding for the H2020 Associated Countries was highly concentrated. Norway and Switzerland both accounted for about 30% of the €261m budget, closely followed by Israel (about 25%). The remaining 15% of the budget was to the benefit of stakeholders in Turkey (7%), Serbia (4%) and nine other countries accounting for maximum 1%.

As for the Third Countries, their involvement in the H2020 LEIT programme part was limited to 506 participations or 2% of the total participations (Figure 20, below). Eleven high-income countries[72] accounted for about 50% of these participations (236 participations) and low- and middle-income countries for about 30% (159 participations). The five BRICM[73] countries accounted for the remaining 20% (111 participations).

Among the high-income and BRICM countries, organisations based in the US had the highest rate of participations (91), followed by China (55), South Korea (39), and Taiwan (38). In total, 47 low- and middle-income countries participated; South Africa, Kenya, and Senegal were the ones with ten or more participations (18, 12, and 10 participations, respectively).

Figure 20 Participation by industrialised countries and BRICM in the LEIT programme part



Source: Technopolis Group, based on CORDA data (15/11/2021)

5.1.5. Project management and monitoring procedures

Stakeholders consulted during this study highly appreciated the pragmatism by the EC in terms of project management, in particular the flexibility in adapting project objectives to changed circumstances in the external environment or the project consortium. Survey respondents also considered the reporting requirements to be proportionate and the project management and monitoring tools to be user-friendly, including the reporting platforms.

Survey respondents were more critical in relation to the EC's definition of the role of the project coordinators and the costs budgeted for project management tasks. Close to half of the survey respondents considered that the definition does not cover all aspects needed for ensuring project success; an equal share of respondents stated that the actual time spent on management exceeded the budgeted costs. As such, project coordination is perceived as going beyond the oversight of the administrative, financial, and legal aspects and is considered key for attaining the expected project results.

Many survey respondents made use of professional research management service (RMS) providers to support project coordinators' efforts to manage the administrative, financial, and legal aspects of increasingly large and complex FP projects. Efficiency considerations were the main drivers for the involvement of RMS providers. For the industry actors, there were also risk management consideratons

[72] Categorisation based on the current World Bank classification of countries into four income groups: low-, lower-middle, upper-middle and high-income countries, (https://blogs.worldbank.org/opendata/new-world-bank-country-classifications-income-level-2021-2022).
[73] Brazil, Russia, India, China, and Mexico.

in the project coordinator role. Research Organisations highlighted problems in the availability of the needed knowledge, skills and/or human resources.

Project coordinators that made use of RMS providers emphasised the highly positive outcomes, especially on the quality of the research activities and the project results. They also mentioned that it freed up time for project coordinators to invest in communication with end users and external stakeholders.

The frequency/intensity of the use of these RMS providers in the LEIT programme projects is unclear since it is not captured in the CORDA database. About one in ten survey respondents, mainly active in the private sector, indicated that it had been the case in their projects.

5.1.6. Information and communication processes and tools for valorisation

Processes and tools for evidence-based policymaking

The Evaluation Study on the internal coherence and relevance of H2020 and its policy mix[74] highlighted the efficiency of the EC monitoring and evaluation (M&E) system, i.e. the monitoring tools and the mid-term and final FP evaluations, in adjusting the programme implementation and refocusing (to a certain extent) the directionality of the funding focus and definition of the calls. The study assessing the Horizon 2020 Focus Areas[75] made a similarly positive assessment. It highlighted the strengths of the M&E system for EC accountability purposes, i.e. providing a fairly good idea that European public money is well invested and that projects are achieving what they promised and planned. It, however, also considered that the M&E system provides only limited insights on the systemic effects of the FP on the R&I system as a whole to inform the programme design and choice of policy mix.

Important limits of the current M&E system that emerged from our analyses related to the capacity to monitor and assess:

- The FP's effectiveness in fostering knowledge ecosystems – overall and specifically in relation to the new funding modalities (including the FSTP – see Section 5.1.1, above).
- The effectiveness of the instruments used in relation to their function in supporting R&I (e.g. collaborative research versus demand-side innovation) and the type of research conducted (the blurry boundaries between RIA and IA in terms of TRL).
- The FP's effectiveness in the creation and diffusion of innovation, currently relying close-to-exclusively on patent data. In this context, the importance of initiatives such as the Innovation Radar estimating the 'market creation potential' of FP-funded projects is to be mentioned[76].
- The FP's effectiveness in creating (longer-term) spill-over effects to the broader R&I system.

Communication and valorisation strategy

The main problem for market deployment and valorisation of research results is the simultaneous abundance and lack of information on the exploitable results of H2020 projects. The lack of common standards, requirements or understanding of what level of detail is appropriate to sufficiently inform specific stakeholders (Industry, citizens, policymakers) about R&I project results represents another important challenge.

Stakeholders responding to our survey appreciated and attributed a high level of importance to the EC dissemination activities and platforms such as the Horizon Results Booster (HRB) and Platform (HRP), and in general, to the EC communication activities to stakeholder groups. Interviewees highlighted the importance of a centralised approach to these activities (rather than in the context of individual projects) to ensure professional results. We cover this topic further in Section 6.3.2, below.

[74] Daimer S., Seus S., Afghani N. Wang A., Kroll H., Howoldt A., (2022) Evaluation Study on the relevance and internal coherence of Horizon 2020 and its policy mix. Interim report 2. Fraunhofer Institute for Systems and Innovation Research ISI, Technopolis Group, Austrian Institute of Technology, 4front. (Second Interim Report – LEIT case study – not published).

[75] European Commission (2021) Opportunities and Challenges in Targeted Funding of Research and Innovation: Lessons learnt from the Horizon2020 Focus Areas and implications for Horizon Europe Missions, CWTS, Technopolis Group, DG RTD.

[76] Nepelski, D., Market creating innovations in the EU Framework Programme, methodology behind the innovation radar's market creation potential indicator, Joint Research Centre, 2020.

5.2. Cost-effectiveness

We address the topic of cost-effectiveness in terms of direct leverage effects created by the FP and partnerships.

5.2.1. Cost-effectiveness of the LEIT programme part

Overall, the private-sector contribution to research funded under the H2020 LEIT programme part was substantial.[77] In total, industry contributed a total of €3.93bn to the costs of their projects, accounting for 42% of the project costs. In terms of leverage, it meant that for every euro invested in industry projects by the EC, €0.7 was invested by industry.

The contribution of the private sector varies significantly depending on the size of the enterprise. Overall, about 70% of the private contribution (€2.9bn) was financed by large enterprises, while SMEs contributed €1bn or 30%.

5.2.2. Cost-effectiveness of the partnerships

Public-private partnerships leverage co-funding from both public and private sources. Their capacity to foster/attract co-funding from the public sector highly depends on the implementation model of the partnerships. On the private side, the PPPs' good understanding of channels for upscaling enables them to address market failures and lower the risks for industry wishing to co-invest.

The **two JUs** relevant to this study are based on a tripartite model of governance and funding. In the case of the ECSEL JU, the total budget for the H2020 period (€4.7bn) derived from three sources: EU funding (25% of the total budget), financial contributions from 20 Member States (about 25%), and contributions from beneficiaries, mainly in-kind (about 50%). An ECA report[78] showed that the private members from ECSEL fully committed their in-kind contributions by signing grant agreements. It also stated that ECSEL was on target to reach a 'leveraging effect' of private co-funding higher than the one set in the Regulation. The EuroHPC JU is based on the same tripartite model. The EU planned a contribution of €536m from the 2014-2020 MFF, a similar amount was planned to be allocated by the participating countries. In EuroHPC, participating Member States financed part of the eligible project costs not covered by the EU, while private members contributed on top of the maximum eligible costs of grant actions. The above-mentioned ECA report considered that EuroHPC was at high risk of not achieving private members' minimum in-kind contribution targets (private and national co-funding) by the end of the implementation of H2020 projects.

With regards to **cPPPs**, the EC established contractual arrangements to allocate an indicative amount of EU budget for the research and innovation projects reflecting these partnerships' SRIA during the 2014-2020 period. In turn, the private partners of the cPPPs committed to invest funds in R&I activities specific to the partnership domain. A leverage factor of investments for industrial deployment in the range of 5 to 10 was often established between the partners (e.g. leverage factor of 4.65 for the FoF cPPP, 8.5 for the SPIRE cPPP, or 7.8 for the Big Data cPPP).

With regards to **EIT KICs**, for the period of 2014 to 2019, the EIT Digital received €398m in EIT contributions, and €114m from external sources. The EIT Raw Materials received €179m in EIT contributions including €40.6m from external sources. For both KICs, the 'funding by external sources' related to co-funding by partners (in cash) or complementary contributions by partners or third parties (mostly in kind).

With regards to the **P2Ps**, EMPIR had an allocated budget of €600m of which €300m was brought in by participating Member States and €300m by the European Commission, as per Article 185 TFEU. The funding data for the ERA-NETs was incomplete.

6. Effectiveness

We introduce this chapter by providing information on the limits to the assessment of the H2020 effectiveness in this evaluation (Section 6.1). In Section 6.2 we then summarise the factual evidence on the extent to which the LEIT programme part reached the scientific and technological, and innovation-

[77] Under H2020, private sector co-funding was required only for the Innovation Actions.

[78] ECA (2022) Annual report on EU Joint Undertakings.

related outcomes and desired results. In Section 6.3 we summarise our findings on the factors that enabled or hindered these outcomes and results.

6.1. Limits to the assessment

The timing of this evaluation, combined with the uneven distribution of the H2020 budget for the Digital and Industrial Transition over time, especially in the LEIT programme part (see Section 3.2, above), puts a **significant limit** on the assessment of H2020's overall effectiveness.

Under the LEIT programme part, close to 75% of the projects (2,438) concluded their activities by the end of 2021, accounting for 53% of the funding. As shown in Figure 21, the pattern is similar for the three LEIT programmes. Considering a lapse time of two years for project effects to materialise (thus, projects ending in 2019), the evaluation could capture outputs and results only for about 60% of the projects in LEIT ICT and LEIT NMBP, and only about 50% of those in LEIT Space. Overall, these projects accounted only for about 30% of the total LEIT programme part budget (specifically, 32% in the ICT and Space programmes and 28% in the NMBP one).

The H2020 contribution to the DIT overall shows a similar pattern: for each H2020 DIT research area, the evaluation was able to assess outputs and results only for about half of the projects, accounting for only around a third of the H2020 funding.

Figure 21 Distribution of projects and EU contributions by year (project end date)

Source: Technopolis Group, based on CORDA data (15/11/2021)

6.2. Achievement of the objectives

We report on evidence collected along the three major dimensions in the impact pathways: we cover the effects in the scientific sphere (Section 6.2.1) followed by the effects from an economic perspective (Section 6.2.2) and those in the societal and policy spheres (Section 6.2.3). In Section 6.2.4 we focus on the partnership effects. The **full analyses** are reported upon in Annex IV (Data analytics on IPR and innovation) and Annex V (Bibliometrics analyses) to this report (separate documents).

6.2.1. Main (expected) scientific outputs, results, and impacts[79]

Self-declared outputs[80]

Up to 15 November 2021, participants in the LEIT programme part self-declared in CORDA a total of 28,857 publications deriving from their research in 3,161 projects. Overall, LEIT participants therefore declared 9 publications per project, on average, which is below the average of 12 publications per project reached under FP7 (data covering the 2007-2015 period) (Table 8, below).

The H2020 LEIT programmes performed less well than the FP7 programmes also when considering the 'average number of publications per €1m', thus accounting for the differences in the level of concentration or fragmentation under H2020 and FP7: participants in the H2020 LEIT programmes self-

[79] The detailed findings are provided in Annex V – Bibliometrics report (separate document).
[80] The number of self-declared outputs are as they were provided in CORDA. This may include participant reporting errors, such as 'background patents'.

declared 2.8 publications per €1m versus 3.5 under FP7.[81] The performance was slightly better when not accounting for the H2020 new instruments (the SME Instrument and PCP/PPI) but still lower than under FP7 (2.9 publications per €1m).

Table 8 Self-declared publications in the LEIT programme part compared to FP7

	FP7 Cooperation (ICT, NMP, Space)	H2020 LEIT programme part
Av. n of publications per project	12.2	9.1
Av. n of publications per million €	3.5	2.8

Notes: H2020 data for all projects funded, dd. Nov.15, 2021; FP7 data on scientific publications documented in OpenAIRE, downloaded on 27 October 2015
Source: Technopolis Group, based on CORDA data (15/11/2021); data on FP7: Fresco, L.O. et al (2015)82

Scientific outcomes and results

The clearest effects of H2020 support for the DIT was in terms of enabling open access publishing and fostering research-industry co-publications. On these two dimensions, H2020 enabled researchers to achieve higher performances than in their other, non-H2020-funded publications. Research funded under the H2020-DIT and LEIT programmes also generally stood out from research in comparative countries in terms of research-industry and international co-publications.[83]

Open access (OA) publishing is one of the dimensions where H2020 support has had the most impact. Positive, large, statistically robust 'differential impacts' on the propensity to publish under an OA modality have been found in the DIT-related set of publications deriving from H2020-funded research (in all research areas) as well as in the three ICT, NMBP and Space LEIT programmes. Shares of OA publications in the LEIT programmes ranged from 60% (LEIT ICT) to 80% (LEIT Space), showing an increase compared to FP7. Open access scores were also generally above those for non-FP funded research in the EU28 and other international comparators.

DIT-relevant research under H2020 (specifically research related to the Digital Economy and Industrial Technologies) and research in all LEIT programmes performed better than under FP7, the (non-FP) EU28, and when compared internationally in terms of research-industry co-publications. The effect of H2020 funding relative to non-FP funded research was apparent especially in the DIT Industrial Technologies research area and the LEIT NMBP (+4.8 percentage points) and LEIT Space programmes (+3.4 percentage points).

DIT-relevant research under H2020 (in all research areas) stood out also in terms of international co-publications, compared to non-FP funded research in the EU28. However, except for research in the Space Technologies area, the share of international co-publications was at similar levels as under FP7. Also, while the level of international cooperation was generally higher for H2020 than for selected international comparisons, some countries showed better results. Specific non-LEIT programme parts stood out compared to EU28, FP7 and international comparisons, in particular ERC (70%), FET (60%), MSCA (69%), and SC5 (63%). The results were less clear for the LEIT programmes with the levels by programme not really standing out. Still, a positive effect on supported researchers was in LEIT-Space, which was the only thematic area that stood out compared to other countries.

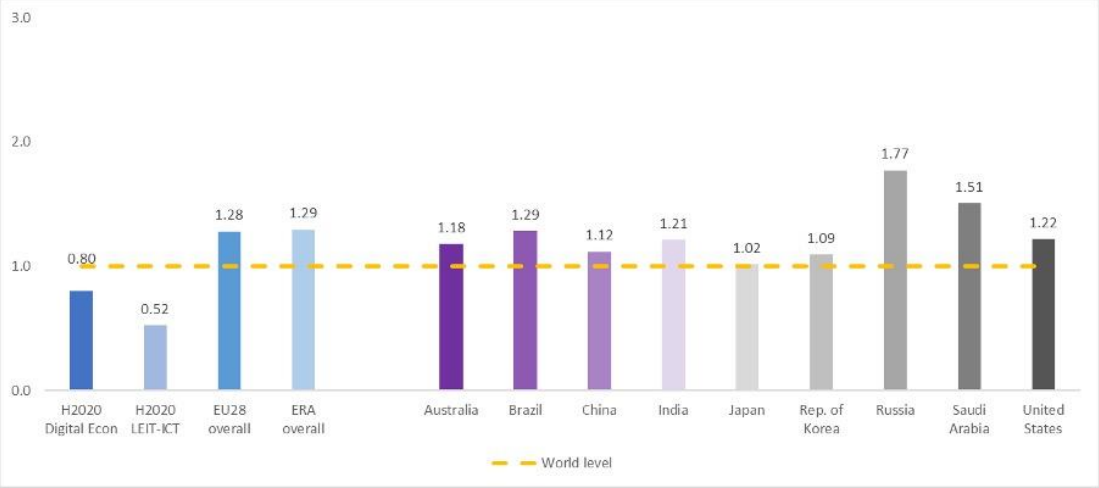
[81] It should be noted that findings based on self-declared outputs should be treated with extreme caution. While they allow for a comparison to the data reported in previous FP evaluations, this data does not account for potential duplicates or non-reported publications nor does it control for disciplinary differences in publishing cultures, meaning that individual publications may not capture the same level of value and efforts between different subfields and LEIT thematic areas. Data at LEIT thematic area level should therefore not be compared and/or interpreted as indications of effectiveness. In addition, it should be noted that, in general, publication volumes cannot be used as indicators of programme effectiveness (see also Annex V Section 2.2.2).
[82] Fresco, L.O. et al (2015) Commitment and coherence essential ingredients for success in science and innovation – Ex-post Evaluation of the 7th EU Framework Programme (2007-2013), European Commission.
[83] For information on the methodology employed in the bibliometric analyses, please consult Annex VI to this report.

Results were inconclusive as regards cross-disciplinary research.[84] By and large, H2020 DIT research performed slightly above world level[85] but not differently from FP7 and non-FP funded research when it came to its share of highly *multidisciplinary* journal publications. For its share of highly *interdisciplinary* publications, H2020 DIT publications performed at the world level, which was on par with FP7 publications and slightly below non-FP EU28 publications. It appeared that journal publications thematically aligned with the overall DIT area were generally unlikely to be among the most highly interdisciplinary within their fields.

Levels of cross-disciplinarity varied among the three DIT research areas and the LEIT programmes, though DIT-relevant H2020 publications in the Space Technologies research area did well in terms of multi-disciplinarity compared to non-FP EU28 research and research in the international comparator countries. In addition, LEIT Space publications had a 74% likelihood of being included amongst the group of highly multidisciplinary publications at the world level, and 41% likelihood of being included amongst the group of highly interdisciplinary publications. For LEIT NMBP publications, the likelihood was considerably lower (67% for multi-disciplinarity and 12% for interdisciplinarity).

A red flag must be raised when it comes to cross-disciplinarity in the DIT Digital Economy research area and the LEIT ICT programme. DIT publications in this field performed well below all international comparisons, and below the non-FP EU28 research and ERA averages in terms of interdisciplinarity (Figure 22) as well as multi-disciplinarity. LEIT ICT publications showed the lowest level of cross-disciplinarity among the LEIT programmes: compared to the world level they were 21% less likely to be highly multidisciplinary and 20% less likely to be highly interdisciplinary.

Figure 22 Normalised shares of highly interdisciplinary publications in H2020-DIT Digital Economy publications, with comparisons to FP7 and EU28 baselines and international comparisons (2014-2021)



Note: Comparison of H2020-DIT Digital Econ and LEIT-ICT results to international comparators is subject to important limitations
Source: Scopus and eCORDA databases processed by Science-Metrix and Technopolis

Scientific impacts

Scientific excellence (defined through the lens of bibliometrics as citation impact profiles) was one of the areas in which H2020-funded research recorded its strongest and clearest achievements.[86]

For DIT overall, its individual research areas as well as the three LEIT programmes, analyses show higher the Citation Distribution Index (CDIs)[87] and larger shares of highly cited publications than for

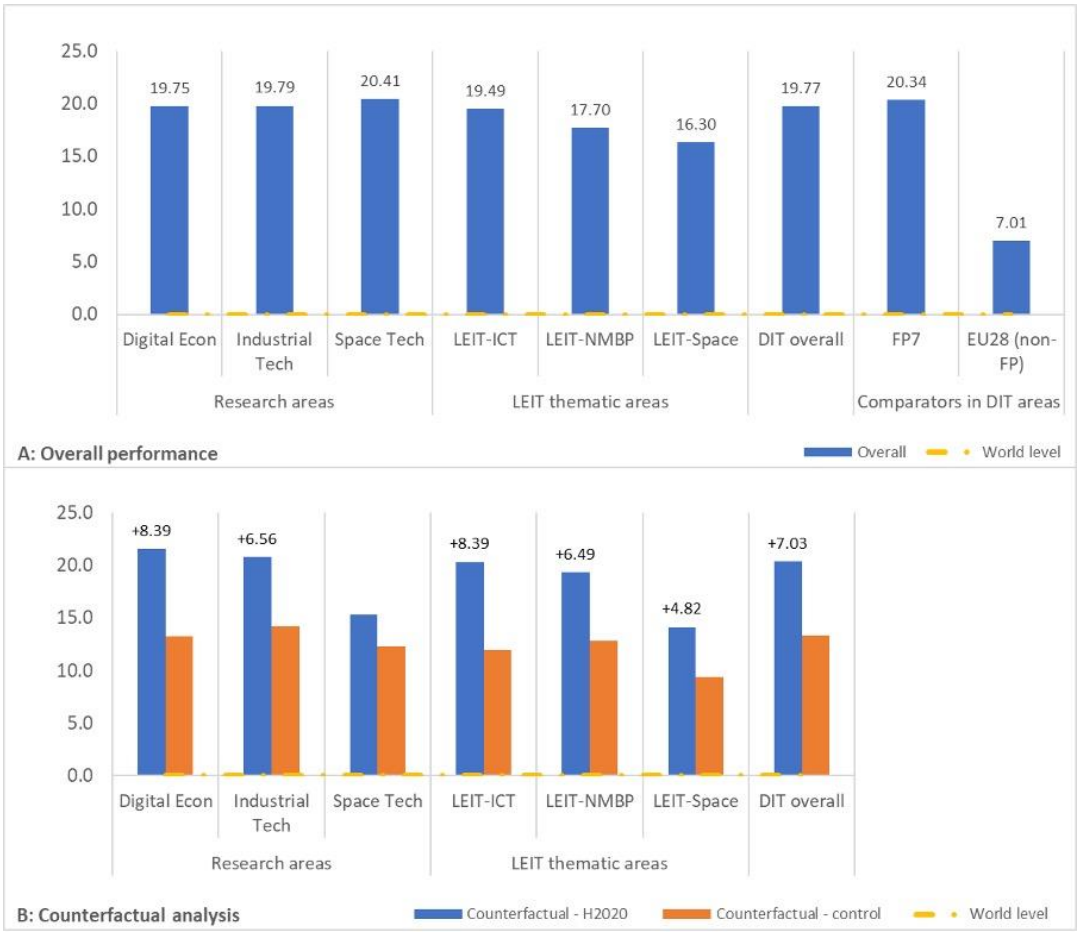
[84] Science-Metrix measures cross-disciplinarity through two sets of indicators: an indicator of disciplinary diversity at the author (DDA) level within journal publications, indicative of multidisciplinary collaboration, otherwise known as multi-disciplinarity**,** and an indicator of disciplinary diversity in the references (DDR) cited in journal publications, indicative of interdisciplinary intellectual integration, otherwise known as interdisciplinarity. Multi-disciplinarity and interdisciplinarity were calculated for the top 10% share of publications amongst the most highly multidisciplinary and interdisciplinary within their subfields and year.
[85] The average for any given paper as recorded in the full Scopus database.
[86] Citation impact indicators are not calculated at all for publications released in 2020 and 2021 and are only computed for certain types of journal publications, namely, full research articles and reviews. As such, findings on citation impact produced as part of this evaluation are therefore early signals. However, these early signals point toward scientific excellence of DIT as a result of H2020 support.
[87] The Citation Distribution Index is the sum of the weighted share of each decile (or each 10%) of a distribution of publications, ranked by citation count (i.e. the 1st decile includes the 10% least cited publications, the 10th decile includes the 10% most cited publications). This indicator is also normalised by year and by subfield of science. The CDI is normalised to 0 (i.e. the world average). A score above 0

(non-FP funded) research in the EU28 and international comparisons – except for Australia. A comparison of H2020-supported papers to non-FP supported papers by the same H2020 authors suggested that the programme has also been effective in improving the performance of awardees. The fact that FP7 performed similarly to DIT overall and its research areas may reflect the continued effectiveness of FP support on this dimension.

Of particular note were the high CDI scores recorded for the ERC (25.5) and MSCA (23.6) publications, well above the DIT overall level (19.8). FET publications' CDI (19.9) was very close to the DIT overall level. In the three cases, scores were very much above the EU28 average of 6.4.

For the LEIT programmes, scores for the Citation Distribution Index ranged from 16.0 (LEIT Space) to 19.0 (LEIT ICT) (Figure 23).The LEIT programmes performed well compared to the world level (0.0) and EU28 (non-FP with a CDI of 7.0) but slightly lower than FP7 (CDI of 20). The significant differential gains in the three LEIT programmes show that H2020 support effectively increased scientific excellence.

Figure 23 Citation distribution index in H2020 publications, scores and differential changes (2014-2019)



Note: Differential changes in counterfactual analysis are labelled only where statistically robust differences were found

Source: Scopus and eCORDA databases processed by Science-Metrix and Technopolis

In terms of shares of highly cited publications,[88] the LEIT programmes showed strong results, with scores ranging from 1.9 (LEIT Space) to 2.3 (LEIT ICT), in line with the performance at DIT level. Except for LEIT Space (mirroring the DIT Space Technologies area), counterfactual findings for highly cited publications show that LEIT ICT and NMBP publications had a positive, statistically robust difference over parallel publications.

indicates a level of performance above average while a score below 0 indicates the opposite. See Annex VI for full methodological details.

[88] Bibliometric approaches allow the measurement of the share of publications in a publication set that have reached certain thresholds of exceptionally high citation performance. The threshold used for this study is the top decile (top 10%) of publications with the highest citation impact performances in a given year, subfield and document type (Highly Cited Publications, or HCP10%).

Looking at the relative share of the most highly cited papers across DIT full research areas, scores were high and ranged from 2.4 (Industrial Tech) to 2.6 (Space Tech) with an overall value of 2.4 for DIT (compared to the world level set at 1.0). EU28 (non-FP) publications were much lower with a score of 1.2. The ERC (3.1) and MSCA (2.9) recorded very high CDI scores on this indicator, well above both DIT overall (2.4) and EU28 (1.3) levels. FET publications' score (2.4) was on par with the overall DIT level, but well above EU28 average.

6.2.2. Main (expected) economic outputs, results, and impacts[89]

Self-declared technological outputs[90]

Up to 15 November 2021, participants in the LEIT programme part (thus, excluding the Joint Undertakings) self-declared in CORDA a total of 591 IPR applications (483 patents, 63 trademarks, 17 registered designs, 3 utility models, and 25 other IPR), deriving from their participation in 3,161 projects.[91] In terms of instruments, collaborative research projects (both RIA and IA) led to the largest number of (self-declared) patents, followed by the SME Instrument. Pilot lines rank third among the instruments.

The comparative analysis with the FP7 data (covering the 2007-2014 period) in Table 9, below, shows a close to equal performance to the previous FP, both in terms of average number of IPR applications per project (0.2 IPR applications per project in both FPs) and per €10m funding (0.6 IPR applications per €10m under LEIT versus 0.5 under FP7).[92] The new H2020 SME Instrument was, however, highly efficient in producing patent applications, with an average of 0.2 IPR application per project, and especially, 6.1 IPR applications per €10m. When not counting the SME Instrument, the LEIT programmes showed therefore a lower performance than FP7 against the funding dimension, namely 0.4 IPR applications per €10m funding.

Table 9 Self-declared IPR applications in the LEIT programme part compared to FP

	ICT	NMBP	SPACE	Total programme
FP7 Cooperation programme (ICT, NMP, Space)				
IPR application per project	0.1	0.4	0.1	0.2
IPR per €10m	0.4	0.9	0.3	0.5
H2020 LEIT programme part				
Av. n of IPR application per project	0.2	0.3	0.1	0.2
Av. n of IPR application per €10m	0.6	0.7	0.3	0.6

Source: Technopolis Group, based on CORDA data (15/11/2021). Data on FP7: Fresco, L.O. et al (2015)[93]

The rather low activity in the valorisation of the research results is a cause for concern. While the IPR production was at similar levels under FP7 (based on the self-declared outputs), the degree of research valorisation effects seems rather low in light of H2020's stronger innovation orientation compared to

[89] The detailed findings are provided in Annex IV – STI analytics report on IPR and innovation (separate document).
[90] The number of self-declared outputs are as they were provided in CORDA. This may include participant reporting errors, such as 'background patents'. It should be noted that findings based on self-declared outputs should be treated with extreme caution. While they allow for a comparison with the data reported in previous FP evaluations, this data does not account for potential duplicates or non-reported IPR nor does it control for disciplinary differences in, e.g. patenting cultures. Data at LEIT thematic area level should therefore not be compared and/or interpreted as indications for effectiveness.
[91] 328 IPR applications were filed for projects under the LEIT ICT programme, 233 for the NMBP programme, and 30 for the LEIT Space programme.
[92] As for the publications, data on self-declared IPR applications need to be considered with caution. Two things need to be kept in mind when interpreting these numbers. First, not all of these patents were retrievable in the patent database PATSTAT, based on the information in CORDA (essentially, we were able to match 412 of them). Several reasons might play a role: IDs might have been misspelled, applications might have been withdrawn before publication, documents might have been filed in jurisdictions outside the coverage of PATSTAT. Second, in several cases the funded organisations reported patent documents, which are not equal to inventions. An invention can be filed at several (national) patent offices where patent protection is requested. Projects might therefore report several patent applications in the CORDA database for a single invention. While this is technically correct, it is statistically misleading. In sum, for this particular analysis we accept the number of reported patents as they are in CORDA and we do not count inventions, but patent documents here.
[93] Fresco, L.O. et al (2015) Commitment and coherence essential ingredients for success in science and innovation - Ex-post Evaluation of the 7th EU Framework Programme (2007-2013), European Commission.

FP7. Against this background and seeing an R&D investment by the European Commission of €11.6bn over a period of five years, 570 patents in 132 projects appears to be an underperformance.

The identification of the patents against the International Patent Classification (IPC) classes shows that in terms of key enabling technologies, LEIT projects contributed most to photonics (61 patents or 40% of the total), followed by micro/nanoelectronics (47 or 30%), and industrial biotechnology (31 or around 20%).

Economic results

The **innovation orientation** of the LEIT programme projects can be analysed using the Innovation Radar (InnoRadar)[94] data. In the InnoRadar dataset, we find 4,377 innovations in 621 projects. Half of these innovations (50.1%) emerged from projects in LEIT ICT, 46% from LEIT NMBP, and only 3.5% from LEIT Space. Across all LEIT programmes and intervention areas, most of the innovations (between 70-100%) were classified as 'new to the market' innovations (new to the world).

Product innovations are dominant categories in the ICT and NMBP thematic areas. In ICT, service innovations are also prominent in different areas (e.g. cybersecurity, IoT, Advanced computing, NGI*)*, while about one third of the innovations in the NMBP Manufacturing Technologies and Emerging Enabling Technologies areas were process innovations. Absolute numbers are rather low for the LEIT Space programme where out of the 65 innovations reported, 37 are service innovations (56.9%).

Based on the InnoRadar survey responses, research funded under the LEIT programme part led to the creation of in total **52 spinouts/spinoffs,** most of them in the scientific and technological services (19) and the information and communication sectors (18). In the manufacturing sector, only 8 spinouts were founded, and for the four remaining sectors, the sum of spinoffs was also 8.

The analysis of the **maturity level of innovations** at DIT level tends to indicate that innovations were mostly still in their early stages and just emerging or the market yet to be created.[95] Exceptions were found in the ICT IoT and Advanced Computing areas and the NMBP Emerging Enabling Technologies and Advanced Materials areas where some innovations seem to be in their market-creating stage. In general, the LEIT Space Innovation area, encompassing the SME Instrument, produced the most market-ready innovations, on average.

The rather high number of reported DIT innovations combined with the low number of IPR applications and the rather low maturity level of the innovations seem to indicate that the FP gave added weight to project ideas yet to be protected by IPR and diffused, implying there is still some way to go before commercialisation.

Economic impacts

Our analyses of the **economic effects on firm performance** showed that there is a positive association between EU funding under the LEIT programmes and the post-participation firm performance and growth (Figure 24).[96]

Companies that successfully applied for EU funding[97] under the LEIT programmes have reported, on average, higher turnover per employee (interpreted as higher labour productivity) and especially, higher Earnings Before Interest and Taxes, Depreciation and Amortisation (EBITDA)[98] (interpreted as higher profitability) than unsuccessful applicants. This difference is even more pronounced when we compare successful applicants with companies in the control group, i.e. firms with similar characteristics as the successful applicants who did not apply for EU funding under LEIT. The pattern holds when the sample

[94] https://www.innoradar.eu/

[95] It should be noted that the Innovation Radar covers a selective set of projects (about 50% of the collaborative research RIA and IA) and focuses on the three LEIT NMBP areas, the Advanced Computing, IoT, and NGI areas in the LEIT ICT programme, and in the LEIT Space, exclusively the field of Earth Observations. The findings are, threrefore, to be considered as indicative only.

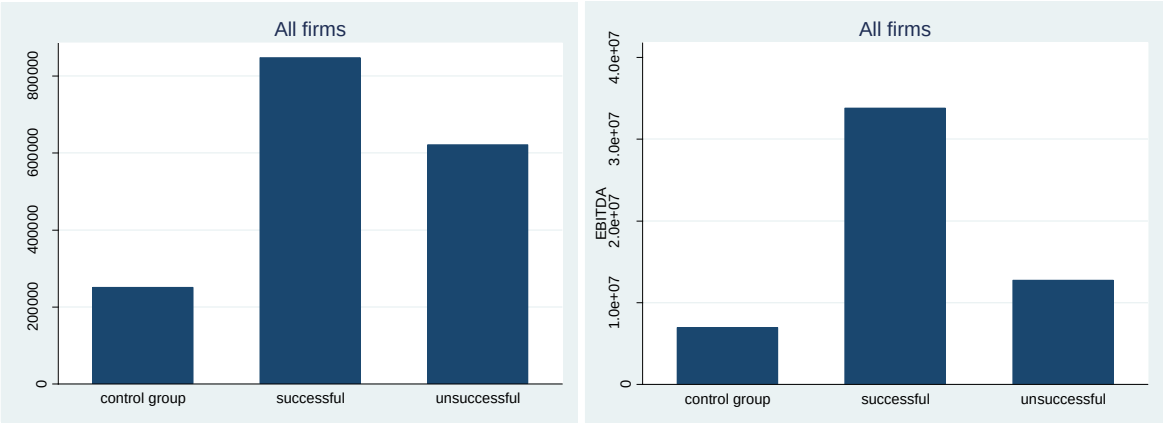
[96] To test this assumption, we performed descriptive analyses and estimated several multivariate regression models. We compared three groups of firms: a) 'successful' participant firms who were supported by the EU LEIT programmes; b) 'unsuccessful' applicant firms who applied for EU projects but were not supported, and c) a 'control group' of firms with similar characteristics who did not apply for EU funding under LEIT. The control group served as a basis of comparison for the performance of funded firms.

[97] The analysis included 11,323 companies that received EU funding in LEIT (successful applicants), 33,412 companies that were unsuccessful in receiving EU funding in LEIT (unsuccessful applicants), and 7,443 statistical twin companies, which did not apply for EU funding in LEIT (control group). For the sampling details of the control group, see Annex IV to this report (separate document).

[98] EBITDA is useful to compare the operating results of companies without the influence of fluctuating tax rates or different interest rates on debt.

is split by large companies and SMEs, even though the positive effect of EU funding on the higher productivity is more pronounced for SMEs than for large enterprises.

Figure 24 **Turnover per employee (left) and EBITDA (right) for successful applicants, unsuccessful applicants, and the control group**



Source: Fraunhofer-ISI, based on ORBIS database by Bureau van Dijk, October 2022

Based on the profile of the FP participants, the economic effects on industry participants depicted above can be expected to create **structural effects** especially on the manufacturing, information and communication, energy supply, and transport and storage sectors.[99]

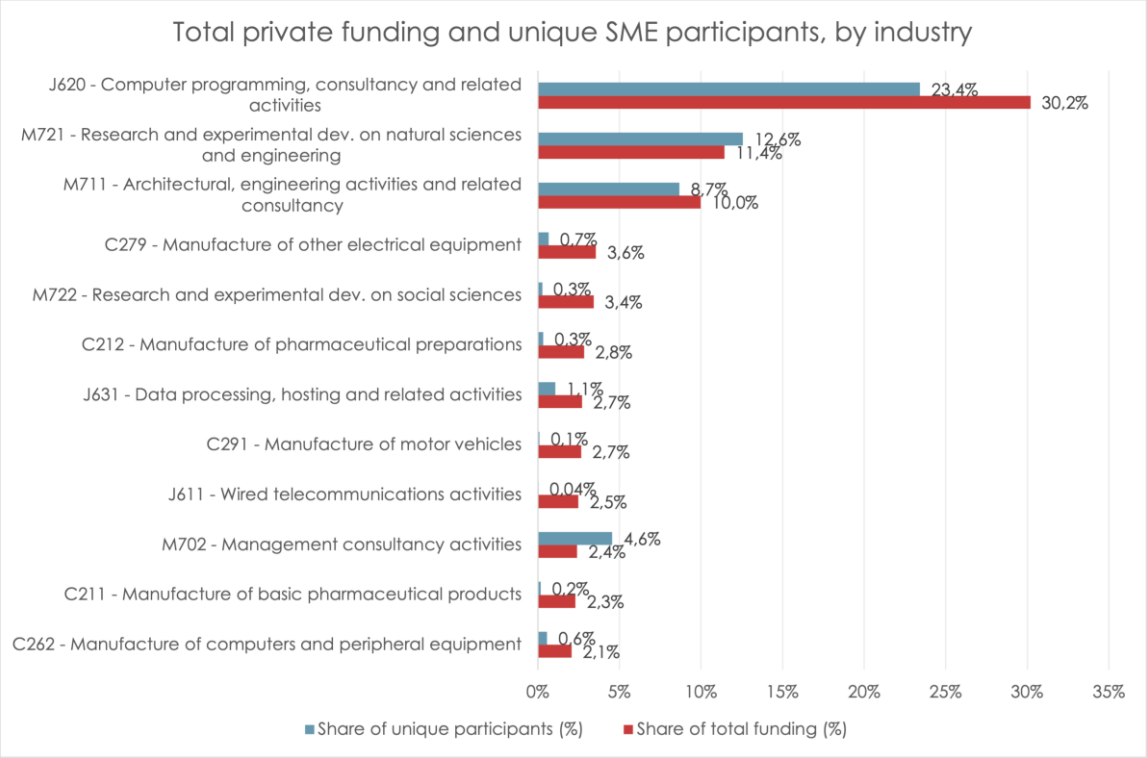
Our analysis of the **post-project private funding of R&I in SMEs** shows that 11% of the SMEs participating in the LEIT programmes (548 out of the 5,085 unique participants) were successful in raising private funding – a total of €9.36bn – following their H2020 activities. The analysis was conducted by combining CORDA and Crunchbase data covering all types of funding rounds publicly announced (upon availability of data).[100] The private funding raised was spread over 1,232 funding rounds and raised between 2014 and 2022. Most of this amount was raised in venture capital and equity funding rounds (respectively 61% and 21%). Debt represents 7% of the total amount, while other types of financing were marginal (convertible note, corporate round, seed, crowdfunding, non-equity assistance, and other/non specified financing types – less than 3% each).[101] Taking account of their share in the LEIT SME population, the SME Instrument was the action type most conducive for participating SMEs to achieve post-project private funding, followed by RIAs. For the IAs, the share of funding reached was not proportionate.

Overall, SME participants active in the high-value-added service industries accounted for the highest shares in private funding. Specifically, this regarded SMEs active in the computer programming (30%), R&D (15%), engineering (10%), data processing and wired telecom activities sectors (3%, each) (

Figure 25). In manufacturing, no single sector stood above the others. However, several manufacturing sectors raised high shares of funding compared to their size in the LEIT SME population. These included sectors making computers and other electrical and peripheral equipment (jointly 6%), the manufacture of pharmaceutical preparations and basic pharmaceutical products (jointly 5%), and the manufacture of motor vehicles (3%)

[99] For more details, see Annex IV to this report (separate document).
[100] An extensive description of the methodology can be found in Annex IV – Data analytics on IPR and innovation.
[101] It should be noted that the (variegating) levels of venture capital and equity funding availability in the different countries strongly influence the geograophical distribution of the private funding.

Figure 25 Total private funding and unique SMEs participants, by main NACE codes



Source: Technopolis Group, based on CORDA and Crunchbase data, October 2022

6.2.3. Main (expected) results and impacts in the societal and policy sphere

Policy-related outcomes and impact on policymaking

Journal publications may contain findings or evidence of interest in the policymaking process, as it is broadly understood, ranging from syntheses of evidence prepared by scientists for a policymaking public, to parliamentary and regulatory work on policy change. New databases make it possible to track instances where journal publications have been cited in policy-related documents.

Our analysis showed a strong performance of the H2020 DIT and LEIT programmes' publications in terms of policy-related citations. At the DIT overall level, H2020 publications saw nearly three times more policy-related uptake than the EU28 (non-FP) baseline publications and nearly twice as much as the FP7 baseline publications.[102] The three research areas contributed differentially to this overall score: Industrial Technologies publications recorded a normalised share of publications with at least one policy-related citation of 4.2. Digital Economy publications held a score of 2.9 and Space Technologies had a score of 3.4. Results were similar in the respective LEIT programmes. LEIT ICT publications had the lowest normalised score of 1.8, on par with baseline FP7 publications. However, LEIT NMBP publications and LEIT Space publications saw scores of 3.3 and 3.4, respectively, indicating they received greater interest in the policymaking process than FP7 baseline publications and the world level. However, the counterfactual analysis didn't show that H2020 support has enabled these researchers to reach even higher levels of publications with policy-related citation than in their other publications.

Contribution to EU priorities and United Nation's SDGs

The H2020 DIT and LEIT programmes awarded funding to researchers with a strong propensity (above EU28 average) to publish research thematically aligned with the sustainable development and climate policy priorities and the UN SDGs. Overall, 18% of H2020 DIT-relevant publications contributed to the

[102] It should be noted that the ideal citation window for capturing these citations is three to four years after the journal publication is published, meaning that the current evaluation comes too early to capture most of the expected citations to H2020 and comparable publications. Nevertheless, it is possible to capture early signs of uptake for H2020 outputs as well as of the possible effects of H2020 on this dimension. For example, in comparing the various analytical groups (e.g. H2020 vs. FP7), the scores were normalised to account for publication year and subfield of the publication.

green transition agenda, 23% of publications thematically aligned with at least one SDG.[103] While no statistically definitive evidence was found that H2020-DIT shifted the thematic focus of supported authors toward the Green Deal and SDG objectives, it can be said that the FP favoured projects that were well aligned with these priorities.

Results were mixed when considering specific research areas and LEIT thematic areas. Publications from projects in the DIT Industrial Technology research area drove contributions to the sustainable development and climate **EU policy priorities**.[104]

Related to these green transition priorities, DIT-focused research in general and specific research in the Industrial Technology area showed a comparatively higher performance than FP7 and (non-FP funded) research in the EU28. A similar outcome can be noted for research funded under the LEIT-NMBP and LEIT-Space programmes. Compared to the EU28 average, a greater proportion of research funded under the LEIT ICT programme was thematically aligned with the policy priorities 'human-centric technological development and industry' and 'safe, secure and geopolitically resilient society'.

When looking at specific **SDG priorities** (Figure 26, below), publications in the overall DIT area were aligned with three SDG priorities. The largest share of the DIT research (and more than expected from the world level) was found to contribute to SDG9 'Industry, Innovation and Infrastructure' (7.3% against 2.1%, leading to a specialisation index of 3.5). This achievement was driven mainly by Industrial Technologies and, to a lesser extent, Digital Economy-related research. The contribution to SDG7 'Clean and Affordable Energy' was solely due to the performance of Industrial Technologies research, while the SDG11 'Sustainable Cities and Communities' performance was mostly due to the contributions of Digital Economy and Space Technologies-related research. Innovation outputs from projects funded in the LEIT programmes mainly addressed SDG7 'Clean and Affordable Energy' (1,141 projects, 22.6% of total), SDG8 'Decent work and economic growth' (1,136 projects, 22.5%), and SDG12 'Responsible consumption and production' (1,119 projects, 22.2%).

Figure 26 **Specialisation indices of DIT-H2020 publications for shares of publications thematically aligned to SDG priorities, by research area (2014-2021)**

SDG	DIT Overall	Digital Econ	Industrial Tech	Space Tech	Share at world level
1	0.1	0.1	0.0	0.8	0.4%
2	0.3	0.2	0.3	1.5	1.1%
3	0.2	0.1	0.2	0.2	13.6%
4	0.3	0.5	0.1	0.0	0.9%
5	0.1	0.1	0.0	0.0	0.7%
6	0.4	0.1	1.0	1.3	1.6%
7	1.6	0.9	3.9	1.1	3.9%
8	0.3	0.2	0.5	0.5	1.2%
9	3.5	2.7	5.6	1.2	2.1%
10	0.1	0.2	0.1	0.1	1.1%
11	1.2	1.6	0.5	1.8	1.9%
12	0.7	0.3	2.3	0.3	1.1%
13	0.6	0.2	1.8	2.3	1.3%
14	0.3	0.0	0.8	2.3	0.7%
15	0.2	0.0	0.5	2.6	1.1%
16	0.5	0.8	0.0	0.3	1.1%
Any	0.7	0.5	1.2	0.8	27.5%

Note: Specialisation index: share of publications contributing to a given SDG in a given breakdown, divided by the equivalent share at world level. Indicator normalised with 1.0 representing world level (average publication-level score in all of Scopus for a given year, subfield and document type). Share at world level: share of publications contributing to a given SDG in Scopus overall, across all subfields and years.

Source: Scopus database processed by Science-Metrix and Technopolis

[103] The degree of alignment with the policy priority on sustainable development and climate change (referred to as the green transition agenda or Green Deal objectives) is computed as the share of DIT-H2020 research containing at least one relevant concept or expression in its title, abstract or keywords. This list of thematic queries is drawn from the topics covered by Societal Challenges 2 to 5.
[104] Some 35% of Industrial Technologies publications aligned with the policy priority, versus 13% and 15% for Digital Economy and Space Technologies, respectively. Note: a part of the LEIT-NMBP activities were in cross-cutting parts of the 2016-2017 and 2018-2020 Work Programme. It specifically includes the field of Industrial Biotechnology and the EEB cPPP. Results related to those parts in terms of sustainbale development have been covered in the H2020 Evaluation Study on the Green Transition.

Outreach to society

Overall, online dissemination and outreach efforts can be considered to have been successful. Compared to the EU28 average, DIT publications received more than double the share of altmetrics mentions in news outlets[105] and mentions on Wikipedia. Results were similar but slightly lower for both news and Wikipedia mentions of publications under the LEIT programmes, ranging from 2.2 (LEIT ICT) to 2.9 (LEIT NMBP) for news mentions and 1.8 (LEIT Space) to 2.9 (LEIT NMBP) for Wikipedia mentions. These results were mainly due to strong overall networking capacities of the funded researchers, but also sometimes because the funding allowed researchers to improve their performance on these dimensions slightly. They can be put in relation to the very strong performance in terms of Open Access publications which help to make scientific results accessible to society.

Impact on responsible R&I

For H2020 DIT overall, and for each of its three research areas, our analyses indicate that the share of women authorship in H2020-supported publications was similar to that seen for FP7 and EU28 (non-FP) equivalents (roughly 20%). Only for the area of Industrial Technologies was the share of women authorship slightly higher (25%). Additionally, the funding from the programme did not appear to exert a positive influence on the H2020-supported publications of awardees relative to their non-FP supported publications in DIT. Similar findings were observed for the LEIT programmes. Again, only LEIT NMBP scored slightly above DIT overall, FP7 and EU28 (non-FP) (26% versus roughly 20%).

No data could be collected nor was evidence to be found in response to the evaluation question related to dual use or unethical behaviour.

6.2.4. Attainment of the partnership objectives

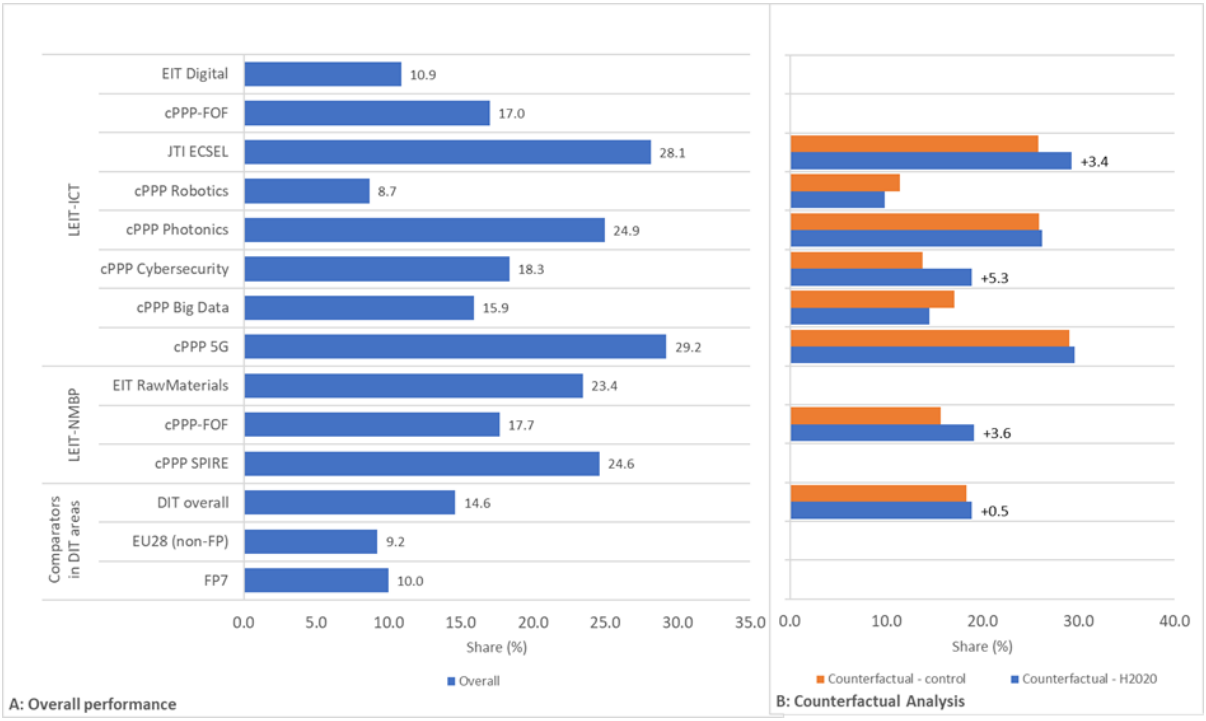
Scientific results and impacts of the partnerships

The various partnership mechanisms recorded converging positive impacts in terms of open access, academic-private co-publication, and citation impact. Ten out of the eleven partnerships for which enough publications were available for bibliometric assessment[106] recorded positive results for open access publishing (the exception was EIT Digital). For six partnerships there was statistically robust evidence of a differential increase thanks to H2020 funding (cPPP 5G, cPPP Big Data, cPPP Photonics, cPPP Robotics, cPPP FoF – LEIT NMBP component and ECSEL JU). In terms of research-industry co-publications, nine partnerships recorded positive findings, For the ECSEL JU, cPPP Cybersecurity and cPPP FoF (LEIT NMBP component), the FP funding created a positive differential effect (Figure 27, below). Citation impact analyses were limited by the low number of partnership publications for which long enough citation windows have elapsed (that is, published in 2019 or before), but initial findings show almost all partnerships recording strong scores in the descriptive analysis (not enough publications were available to test for differential support effects).

[105] Altmetrics are a set of methods that aim to track online dissemination efforts of and online attention towards research findings (mainly as they are contained within journal publications). The altmetric component of outreach to society has been operationalised by considering mentions towards journal publications made in two sources: Wikipedia articles and online journalistic news articles (from the online content of dailies such as *Le Monde, Bild, New York Times*, but also from some aggregators of university press releases such as phys.org). See Annex VI for further details.

[106] These partnerships are the JU ECSEL, the EIT KICs Digital and Raw Materials, and the cPPPs 5G, Big Data, Cyber-security, FoF, Robotics, and SPIRE.

Figure 27 Share of academic-private co-publications in H2020-DIT cPPP, JTI and EIT-KIC publications compared to FP7 and EU28 baselines (2014-2021) (left); differential changes in academic-private co-publications in H2020-DIT cPPP, JTI and EIT-KIC publications (2014-2021) (right)



Note: For partnerships without a robust finding from the counterfactual analysis (i.e. no bars presented), even descriptive findings should be considered as subject to limitations or large margins of error

Source: Scopus and eCORDA databases processed by Science-Metrix and Technopolis

The dimensions of international co-publication, multi-disciplinarity, and interdisciplinary all saw weaker performances from the partnerships. On international co-publication, 6 out of 11 partnership performances were negative compared with EU28 average (with for cPPP Robotics differential decrease due to H2020-DIT funding), while the remaining performances were on par with EU28 average. On both multi-disciplinarity and interdisciplinarity, 5 out of 11 partnership findings were negative compared to EU28 average (with 5G cPPP and cPPP Robotics recording statistically robust differential decreases due to H2020-DIT funding on one of the two dimensions). Within the remaining performances, four were on par with EU28 average (FoF-ICT, FoF-NMBP, Photonics & ECSEL JU) and two were positive (SPIRE & EIT Raw Materials).

Economic outputs of the partnerships

In terms of patent applications, cPPP-based projects funded under the LEIT programmes and, especially, the Joint Undertakings showed a stronger performance than the 'mainstream FP' projects. On average, 5.8% of the cPPP projects and 13.2% of the projects in the JUs filed at least one patent, compared to 5.4% of the 'mainstream FP' projects. The Joint Undertakings accounted for 22.1% of the total patent output of the LEIT programmes, while the cPPPs accounted for 15%. In relation to trademarks, the absolute numbers were rather low. Essentially, 1.5% of the mainstream FP projects registered a trademark, while the partnerships show a lower level of productivity (0.3% of the cPPP projects and 0.8% of the JU ones). In terms of other IPRs in design or utility models, the absolute numbers were even lower, and cannot be statistically analysed.

Results and impacts in the societal and policy spheres

The partnerships showed a strong performance in terms of their online dissemination. Seven out of the 11 assessed partnerships recorded positive impacts in terms of news and Wikipedia mentions. Statistically robust evidence of differential increase brought about by H2020 funding was identified for ECSEL JU. Two partnerships recorded altmetric achievements on par with EU28 averages (cPPP Big Data and cPPP Robotics) and two either below or with a differential decrease compared to other publications by the same researchers (5G cPPP and EIT Raw Materials). Some positive findings were also achieved by partnerships on the dimension of policy-related citations for their publications. Five out of 11 partnerships recorded findings above EU28 average (cPPP Big Data, cPPP Cybersecurity, cPPP

FoF-NMBP, cPPP SPIRE & EIT Raw Materials), while 5 others recorded achievements on par with EU28 averages. The cPPP Photonics partnership saw a differential decrease on this dimension compared to other publications by the same researchers.

The partnerships showed significant variation in terms of their publications' thematic alignment with the SDGs. cPPP-FoF (LEIT NMBP component) recorded a share of SDG-aligned publications, more than twice the EU28 average, with a high differential gain (+6%) thanks to the FP funding. For the remaining partnerships with robust findings (all related to the LEIT ICT programme), shares of publications thematically aligned with the SDGs were on par with the EU28 average. Alignment with the Green Deal objectives in partnership publications varied greatly. JTI ECSEL publications, for example, were aligned with Green Deal objectives in 21% of cases. However, for all partnerships the share of aligned partnerships was at best on par with the EU28 average and the researchers' performances were similar in their H2020 publications and in their other publications.

6.3. Enabling factors and barriers

An R&I funding programme's capacity to attain its objectives is determined by a mix of two categories of enabling factors. A first set of factors are the ones inherent to the **programme design and implementation**. The former includes elements such as the S&T and thematic focus of the R&I activities and the funding distribution, the latter relates to the instruments adopted in the overall strategic management of the portfolio mix. A primary condition, however, is the capacity of the programme to attract the type of stakeholders and their specific competences needed for the desired effects to occur. This depends on both the alignment of the activities it funds with the primary stakeholder needs and on the focus of the R&I activities funded.

In Section 6.3.1 we investigate the extent to which – and how – the programme succeeded in setting the conditions for an accelerated and (more) inclusive creation and adoption of S&T knowledge and innovation, in response to the stakeholder needs. In Section 6.3.2 we focus on the extent to which the use of specific instruments and their strategic management facilitated the creation of the expected effects. Section 6.3.3 is dedicated to the LEIT programmes' attainment of the directionality needed to create societal value.

These analyses are based on the triangulation (i.e. integrated analysis) of quantitative and qualitative evidence, upon which we report in detail in the relevant Annexes to this report (separate documents). Specifically, this regards the data analytics reports (Annex IV related to IPR data and innovation, Annex V to bibliometrics) and for the qualitative evidence (Annex I which reports on the case studies, Annex II on the partnerships, and Annex VII on the stakeholder consultations, including interviews).

6.3.1. Responsiveness to stakeholder needs

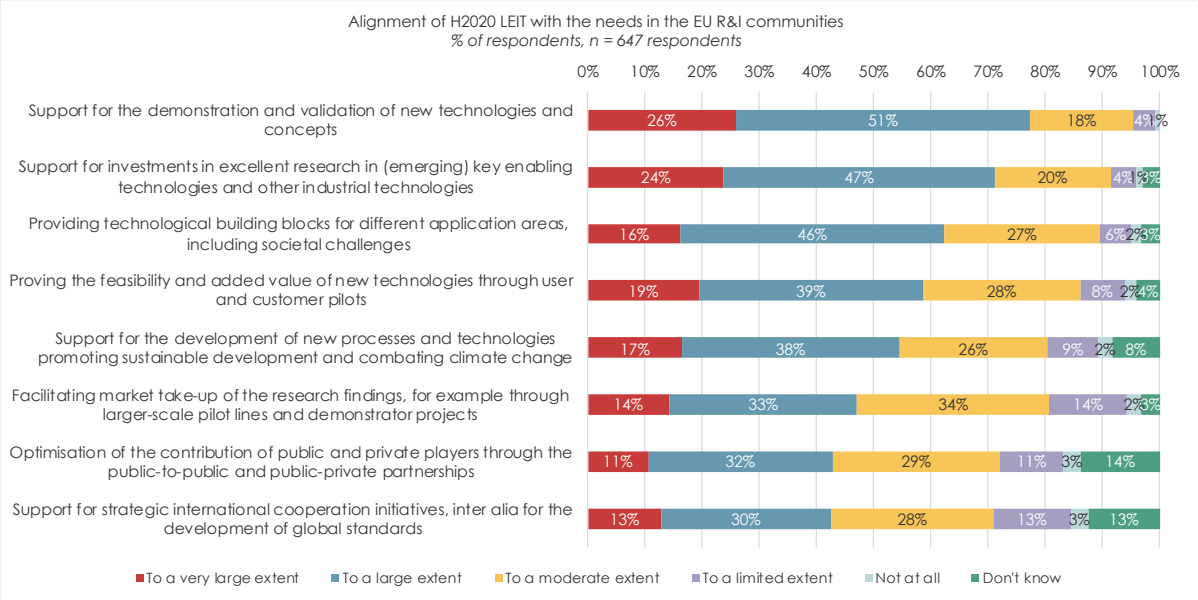
In the sections below we first report on our findings on the extent to which the LEIT programmes were in line with stakeholder needs and, therefore, succeeded in attracting the mix of stakeholders required to reach the desired outcomes. We then cover the benefits and risks deriving from the increasing focus on large and complex big-budget projects. The last sub-section is dedicated to the focus on standardisation and international collaboration in the LEIT programmes.

The creation of knowledge ecosystems and their value

As mentioned in Section 4.1, above, the LEIT programmes were centred on responding to the current technological challenges by optimising the conditions for knowledge creation, sharing, and exploitation. Next to the long-standing collaborative research projects, public-private partnerships and newly created knowledge ecosystems around technology, infrastructures and competence centres are expected to act as arenas for 'knowledge value communities' to interact, share expertise, and define joint visions and roadmaps. Cross-fertilisation is the key word – across technologies, disciplines, and value chains. A close understanding of the (intermediate) user needs is critical to speed up the innovation process 'from lab to fab and app'.

Survey respondents appreciated the overall approach taken (Figure 28); positive views were expressed regarding LEIT's focus on the structuring of R&I communities and the building of knowledge ecosystems across different technological areas, sectors, and countries, covering whole value chains.

Figure 28 Alignment of H2020 LEIT with the needs in the R&I communities



Source: Technopolis Group, stakeholder survey

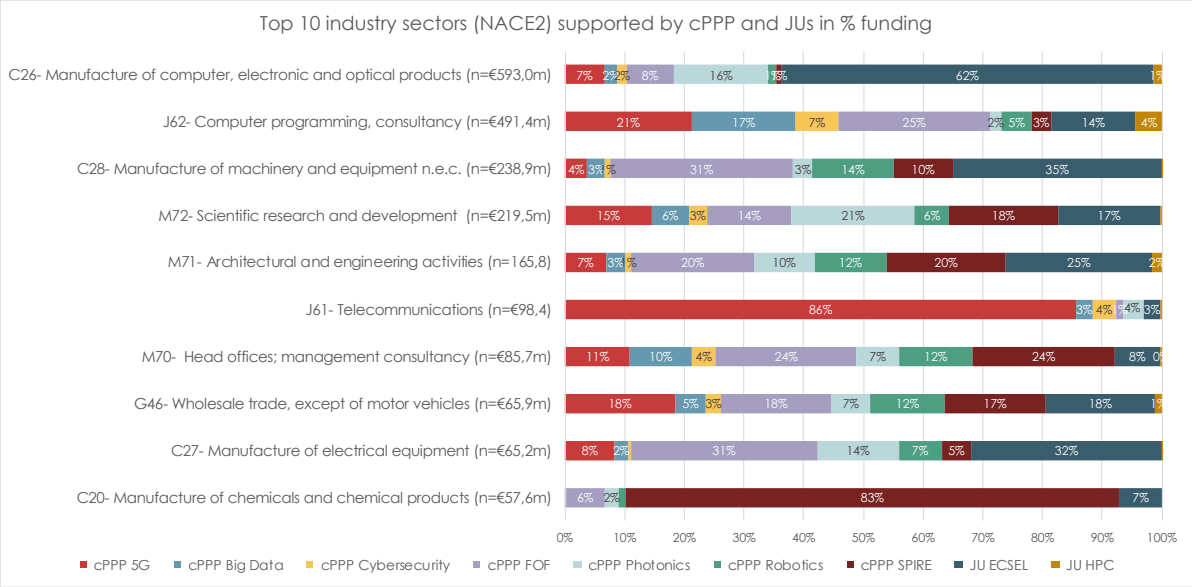
The creation of **research-industry collaboration** is at the core of the collaborative research projects funded under the FP and the analyses reported in Section 6.2.1 show the strong performance of the LEIT programmes in achieving this. This was enabled by the balanced distribution of the funding over the stakeholders. As shown in Section 3.2.2, above, the LEIT programmes dedicated 50% of their funding to the research sector and about 40% to the private sector, close to equally distributed over SMEs and large enterprises.

Equally, public-private partnerships played an important role in fostering collaboration between public and private actors. Overall, the cPPPs showed a funding distribution across the stakeholders that is on par with the LEIT programmes – only a slightly higher share (45%) for the private sector. Similar to the pattern in the LEIT intervention areas, however, there were strong differences in the stakeholder participation across the partnerships, depending on their specific objectives and the maturity of the technologies (upstream research development or downstream market uptake) as well as the composition of the different value chains and market structures. In the cPPP FoF, for example, 25% of the funding was dedicated to SMEs and 23% to large enterprises, while in the cPPP 5G (where the research involved, for example, large telecom companies), the SMEs had a funding share of 21% and Large Enterprises a share of 43%.[107] A similar pattern is visible for the two JUs (EuroHPC and ECSEL). The JU EuroHPC, focused on bringing together the knowledge of Research Organisations, dedicated only about 30% of its funding to actors in the private sector (SMEs accounted for 10%). In the strongly industry-driven JU ECSEL, about 65% of the funding was dedicated to the private sector (SMEs accounted for 15%).

Figure 29, below, shows the industry sectors covered by the different partnerships in the top ten industry sectors at NACE-2 level for which cPPPs and JUs together have distributed most of their funding. Some industry sectors were targeted by only a few PPPs. This was the case, for example, for the telecommunication sector (covered by the 5G cPPP), the manufacturing of computer electronic and optical products sector (JU ECSEL), and the manufacturing of chemical and chemical products sector (cPPP SPIRE). Many PPPs appeared to have adopted a transversal approach, spreading their funding across a wide range of sectors and integrating key value chains.

[107] The full analysis of the stakeholder funding in the cPPPs is available in Annex II to this report (separate document)

Figure 29 Distribution of funding across the top ten industry sectors covered by JUs and cPPPs



Source: Technopolis Group analysis of CORDA database

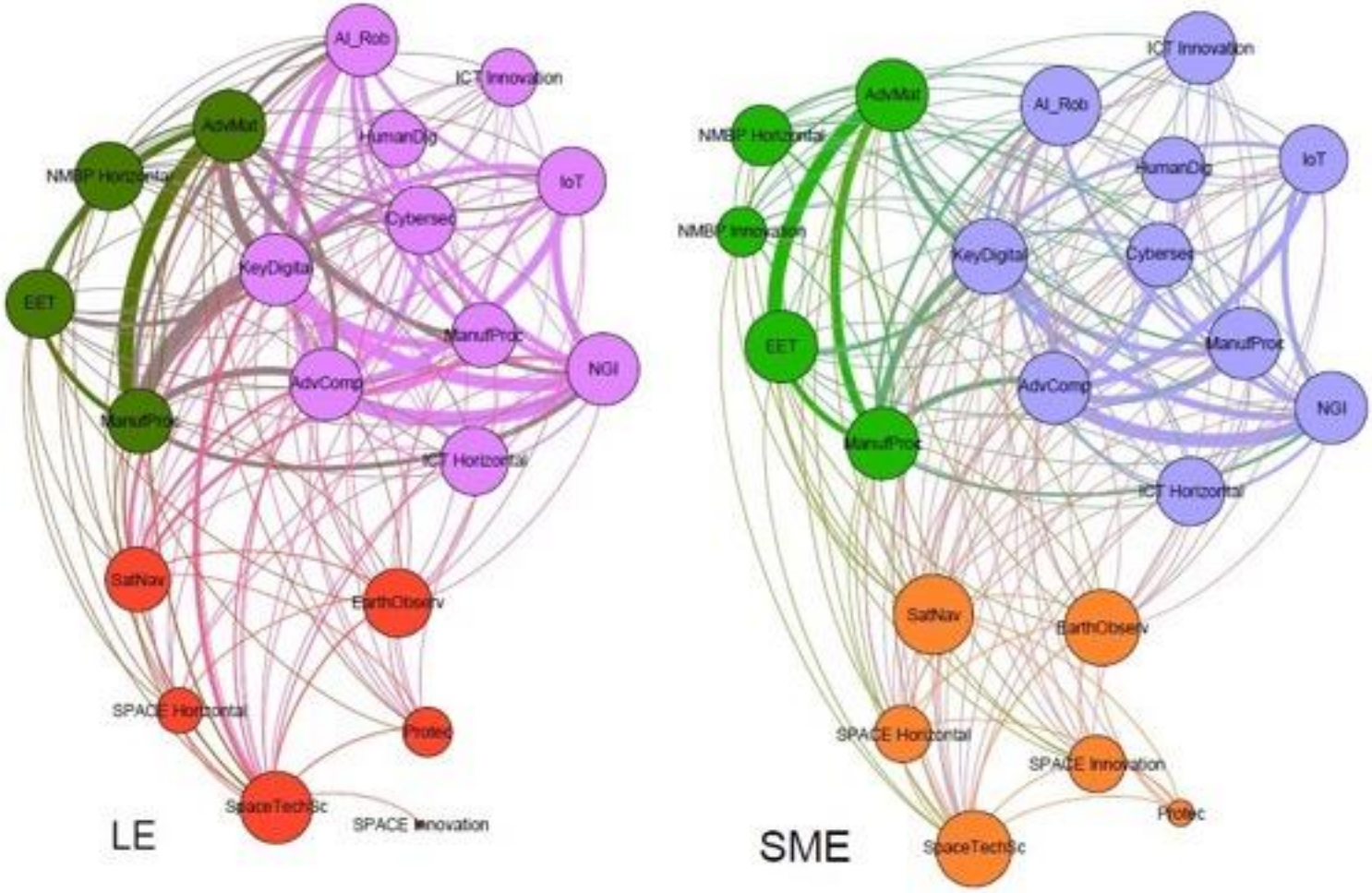
Our analysis of the **participation patterns of industry actors** in the LEIT programmes[108] shows that the LEIT programme part succeeded in setting up the desired cross-sectoral collaboration, attracting organisations active in different sectors across the programmes' intervention areas.

Data on the funding distribution over the private actors active in the manufacturing industry sector shows that various LEIT programmes involved companies active in the same sector. Companies active in the computer and electronics sector, for example, had a relatively strong involvement in the ICT programme but also in the NMBP and especially Space programme, and actors active in the machinery and equipment n.e.c. received a close-to-similar level of funding in the LEIT ICT and NMBP programmes. The NMBP programme stands out for the broad range of manufacturing sectors involved, mainly in the manufacturing research area (cPPP FoF) except for the chemicals sector, which was in the mix of all NMBP research intervention areas.

Our analysis of the **networks of Large Enterprises and SMEs** (Figure 30, below) shows a significant level of participation by **individual** companies across the LEIT programmes and their intervention areas. Individual Large Enterprises, for example, strongly participated in the ICT Key Digital Technologies (KDT) as well as in the NMBP Advanced Materials, and Manufacturing and Processing Technologies. Strong 'interconnections' can be noted also for the ICT Key Digital Technologies (KDT), NGI, and Advanced Computing intervention areas, and for the IoT and Advanced Computing areas. In the LEIT NMBP programme, a high number of individual companies participated in all three intervention areas (EET, Advanced Materials, and Manufacturing and Processing Technologies). For the LEIT Space programme, the interconnection appears strongest between the Satellite Navigation (SatNav) and Space Technologies & Science areas and the ICT Key Digital Technologies intervention area.

[108] The full analysis is reported in Annex IV to this report (separate document).

Figure 30 Networks in the H2020 DIT and intervention areas for Large Enterprises (LE) and SMEs



Notes: The basis of the analysis is the participation of individual companies in multiple programme parts (e.g. if company A participated in an Advanced Materials project and EET

Source: Fraunhofer-ISI, based on CORDA data dd. Nov 2021

When extending this analysis to the **DIT-relevant networks**[109] in the other H2020 programmes (see Annex IV to this report, separate document), strong links can be noted between the LEIT Advanced Computing, Advanced Materials and Key Digital Technologies networks and the networks in the other programmes.

Our social network analysis of economic sectors in H2020 LEIT, illustrating the **intensity and focus of intersectoral research** in the LEIT programme projects (see the Annex IV to this report, separate document), confirms the pattern emerging of both Large Enterprises and SMEs active in the ICT sector contributing to research activities also beyond the LEIT ICT programme. The social network analysis shows that, for example, in the LEIT Space programme, the 'architectural and engineering activities' (711) industry sector is most central, linking to industry sectors such as 'research and experimental development' (721), 'computer programming' (620), and 'manufacturing of air and spacecraft and related machinery' (303). An additional analysis using the Herfindahl-Hirschmann-Index investigating the **concentration of industry sectors** in the LEIT programmes, intervention areas and instruments shows that together with the Artificial Intelligence intervention area, the Manufacturing & Processing Technologies and Advanced Materials intervention areas stood out for their low concentration of sectors, illustrating a higher-than-average level of intersectoral research.

Rising complexity creating benefits and risks

While the trend towards the creation of technology infrastructures and the funding of research projects involving actors across value chains was overall appreciated by the stakeholders, it also implied an increase in the size of project consortia (in terms of number of partners involved) and average project budget (see Section 5.1.3, above). A consequence was an observed increase in the complexity of projects and the resources needed to manage them, setting higher demands in terms of skills, time and effort (see Section 5.1.5, above). Data on the stakeholder funding (Section 5.1.4, above) also shows a clear link between the level of participation among types of stakeholders and the instruments funded.

Research Organisations and competence centres in Higher Education Institutions acted as 'intermediaries' for the creation of the technology infrastructures, taking up the coordination of most of the 134 technology infrastructures (50% and 30%, respectively). Case studies[110] show various enabling factors for these intermediaries fulfilling their role effectively. Of particular importance is their profile, inducing trust among the intended beneficiaries because of their recognised excellence and, in the case of the place-based innovation infrastructures, their proximity to the external environment and therefore understanding of the users' needs. A critical factor for the applying project consortia to win the related calls was the vastness of the consortium members' networks, across various value chains and programme initiatives. Often, the project consortia included organisations that were also active in other projects and partnerships. While these individual participants therefore created a 'bottom-up coherence' between the programme's activities, the phenomenon also points to an increasing concentration of funding for long-standing sFP participants and networks. The case study on the 'Data experimentation incubators' illustrates these findings.

The profile of the intermediaries depicted above, combined with the concentration of the funding distribution on fewer but more complex/costly projects, raises **various concerns**. The study on the H2020 Focus Areas in the last H2020 Work Programme[111] discerned a clear risk of a 'winner takes all' dynamics, creating a barrier for the relevance of the programme to all actors in the R&I system. In addition, a tension between the excellence and cohesion objectives appears in the case of infrastructure-building projects where the context of a competitive research funding programme inevitably implies that the location of these infrastructures depends on the excellence of the competing applicants. Examples are the Digital Innovation Hubs where only 35 out of 279 DIHs registered in 2019 were located in the EU13 and the pilot lines where 32 out of the 34 project coordinators were based in the EU15 (the other 2 were located in Israel and Switzerland). The extent to which, for example, SMEs based in the EU13 will effectively be able to draw benefit from technology infrastructures located in EU15 MS is questionable. It is especially an issue for the place-based infrastructures that aim at fostering local innovation ecosystems. In the case of the DIHs, it required additional initiatives by the EC to boost their availability in the EU13 countries. In addition, seeing the limited availability for the funding of R&I in general in several EU MS, the longer-term sustainability of these technology infrastructures

[109] The projects that we identified throughout the FP as responding to the objective of Digital and Industrial Transition, to the extent possible categorised under the same technological intervention areas.

[110] All full case studies are provided in Annex I to this report (separate document).

[111] EC (2021) Opportunities and Challenges in Targeted Funding of Research and Innovation: Lessons learnt from the Horizon 2020 Focus Areas and implications for Horizon Europe Missions, CWTS, Technopolis Group, European Commission, DG RTD.

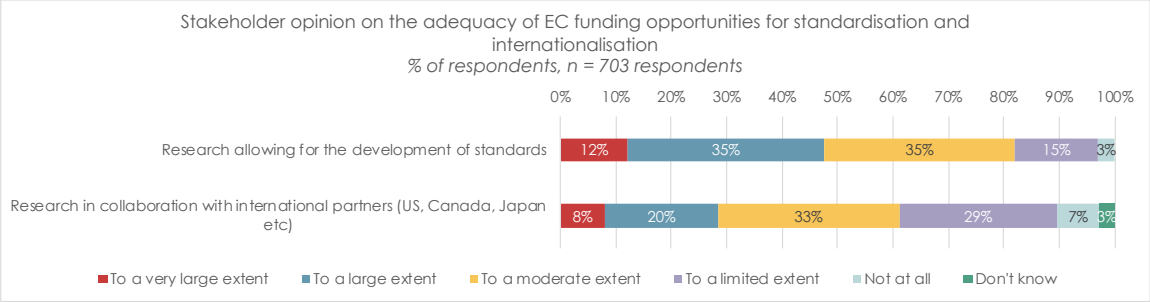
appears uncertain – unless they are part of a broader long-term agreement between the EC and the MS such as the one set up for the EDIH and the cyber-security competence centres.

The increasing complexity, size, and scale of the H2020 projects was a frequent topic of discussion with the stakeholders. There was no consensus on the optimal size among those consulted: some highlighted the importance and benefit of involving many actors across the value chains, others emphasised the risk of reduced SME involvement since larger and more complex projects are likely to be less attractive, especially to manufacturing SMEs. The latter mirrored a lesson learned from the FP7 Interim Evaluation which led to the recommendation in the H2020 Regulation to ensure a balance between large and small projects. On a similar line, the study on the Focus Areas[112] highlighted the need to strike a balance in the amount of funding in relation to the kind of consortium that the project is aiming at, considering what size is manageable and whether the project gears more strongly towards research or societal take-up where scale is a precondition for a wide reach and impact.

Limited standardisation efforts and international cooperation

The availability of standards and conducive regulations is generally considered to be key for the attainment of the EU policy objectives, setting the framework conditions for the desired uptake of innovation. The LEIT programmes appear *not* to have been in line with stakeholder needs in their focus and allocation of funding for the conduct of pre-standardisation research and international collaborations (Figure 31).

Figure 31 Availability of funding opportunities for standardisation and internationalisation



Source: Study survey of H2020 LEIT applicants/participants, successful applicants.

Standardisation was an important topic in projects focusing on EGNOS and Galileo Evolution, Missions, and services, where standardisation and certification options were instrumental in ensuring market uptake.[113] The case studies on nano-safety and the contribution of LEIT ICT calls to the development of 5G and 6G standards equally highlighted the importance of the funding of pre-standardisation projects and the need to enhance their integration in the overall programme portfolio. The case study focusing on 'safety concerns regarding the advancement of nanotechnologies' found that, as such, the projects contributed to enhanced industry knowledge on how to handle emerging risks from nanomaterials so they can be integrated safely into products. At the same time, they supported policymakers and regulators in designing standards. While progress has been made in the field of standardisation as part of the projects, it is noted however that specific calls for projects to promote standardisation activities in the field of nano-safety would have been helpful. Along the same line, the case study on 'the contribution of LEIT ICT calls to the development of 5G and 6G standards' highlighted the importance of the projects in strengthening the knowledge base of EU companies and Research Organisations in 5G-related technologies to catch up with competitors, and underscored the importance of standards and patents in the global technology competition. It also shows that the knowledge created within the research projects needs to be integrated into the ongoing and future 5G standardisation processes, which are dominated by non-EU countries, to better position technologies driven by European stakeholders.

International cooperation in R&I projects therefore offers a key opportunity for knowledge exchange, enhancing the R&I capacities of the actors involved. It can also serve the purpose of enabling the creation – or at least the acceleration – of the process towards the creation of international standards. In this context, the notably limited participation of Third Countries in the LEIT programmes, and

[112] EC (2021) Opportunities and Challenges in Targeted Funding of Research and Innovation: Lessons learnt from the Horizon 2020 Focus Areas and implications for Horizon Europe Missions, CWTS, Technopolis Group, European Commission, DG RTD.
[113] See the related case study in Annex I to this report.

especially participation by actors located in high-income countries (see Section 5.1.4, above), is a point of concern.

Overall, only 6% of the projects in the LEIT Programme part included at least one Third Country participant. The shares of these projects in the LEIT ICT programme intervention areas ranged from about 10% in the NGI and IoT intervention areas to about 2% in the Advanced Computing and AI and Robotics areas. In the LEIT NMBP programme, projects with an international partner were concentrated in the Advanced Materials intervention area (20% of the projects) and to a lesser extent, in the Emerging Enabling Technologies area (14%). In the LEIT Space programme, the shares ranged from 20% of the projects in the PROTEC and Satellite Navigation areas to 13% in the Earth Observation area and 6% in the Space Technologies and Science area. In the PPPs, on average (only) about 3% of the projects included a Third Country organisation. Exceptions were the cPPP 5G with 12% of the projects (9 out of 78) and the JU ECSEL with 10% (10 out of 96).

The limited level of international cooperation in H2020 was an issue recognised already in the H2020 mid-term evaluation report. The Strategic Forum for International S&T Cooperation (SFIC)[114] indicated various possible reasons. Most important is the fact that under H2020, most of Europe's main partners in S&T (emerging and high-revenue countries) were not automatically eligible for EU funding. According to the SFIC, this introduced a factor of uncertainty during the constitution of the consortium and deterred project coordinators from selecting consortium members outside the EU and its associated countries. According to the SFIC, negotiations with the EU's main partner countries and regions regarding the implementation of matching funds for Horizon 2020 were successfully concluded and implemented only late in the FP (after 2017).

In 2016, the Connect Advisory Forum (CAF) advised DG Connect to 1) partner with countries that are recognised as major technological players for the next generation of products and services especially in areas such as networks and communications; 2) explore mutually beneficial joint arrangements with emerging economies which offer opportunities to promote the adoption of European technological platforms and develop new markets; 3) focus on those topics and countries that present the best opportunities for impactful outcomes, in the form of joint activities with leading countries and areas with good potential in topics such as 5G, future internet, IoT, and cloud computing, and to enlarge the geographic targeting of current ICT activities of H2020 (Japan, Brazil) to a few more countries (e.g. South Korea, Mexico).

Interviewees indicated that interest in international cooperation (in the context of R&I projects) was limited among industry actors, especially Large Enterprises.

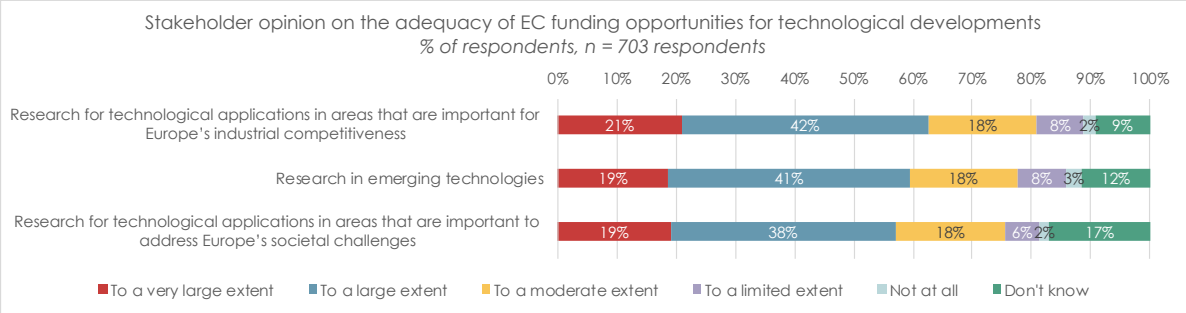
6.3.2. Programme design allowing for advances in the state-of-the-art and technology maturity

The choice of the policy instruments is an important step in the programme design process. As mentioned in Section 4.1.1, above, the LEIT programmes adopted two approaches for their implementation. In the LEIT ICT and NMBP programmes, the dual focus on collaborative research as well as the creation of technology infrastructures implied the use of a broad set of instruments. In the LEIT Space programme, the range of instruments was more limited to the collaborative research instruments, the SME Instrument, the coordination/support actions, and a few public procurement projects.

In this section we focus on three topics related to the implementation of the policy mix: the portfolio management, the knowledge-sharing measures, and specifically regarding the LEIT ICT and NMBP programmes, the partnerships. The stakeholders' positive opinion of the funding opportunities provided by the LEIT programmes and its instruments for conducting different types of research sets the context for the analysis that follows (Figure 32).

[114] European Council (2017) SFIC opinion on international cooperation in the context of the mid-term review of Horizon 2020 and the preparation of the 9th EU Framework Programme for Research and Innovation, European Research Area and Innovation Committee (ERAC), Strategic Forum for International S&T Cooperation (SFIC), ERAC-SFIC 1352/17.

Figure 32 Adequacy of the funding opportunities for technological development

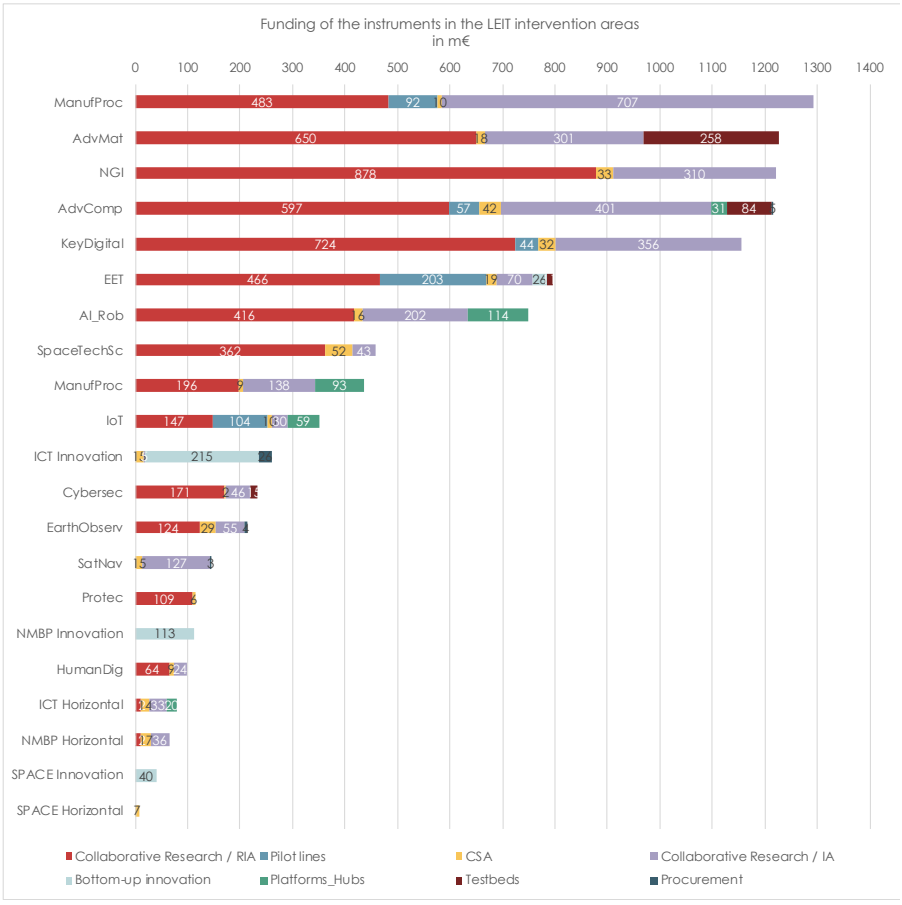


Source: Technopolis Group, stakeholder survey

Portfolio management and coordination

Interviewees as well as case studies point at the critical importance of **using the action types and funding instruments strategically**, taking their function in the overall policy mix into account. When looking at the use of the instruments in the LEIT intervention areas, we note that the choice of the funding instruments appears broadly aligned with the maturity of the technologies and the needs in the targeted industry sectors (Figure 33, below). In the LEIT Space programme, for example, 80% of the funding in the field of Space Technologies and Science, a research-intensive area, was dedicated to RIAs (typically at TRL 4/5); in the field of Satellite Navigation, where technologies have reached market readiness, about 90% of the funding was dedicated to IA actions (typically at TRL 6/7). Synergies with other initiatives were created, for example, through the relatively significant use of 'standard' collaborative RIA actions in the KDT intervention area, creating complementarity with the innovation-oriented activities in the ECSEL JU which (partly) covered the same technological fields and markets.

Figure 33 Policy mix in the LEIT intervention areas



Source: Technopolis Group, based on CORDA data, 15/11/2021

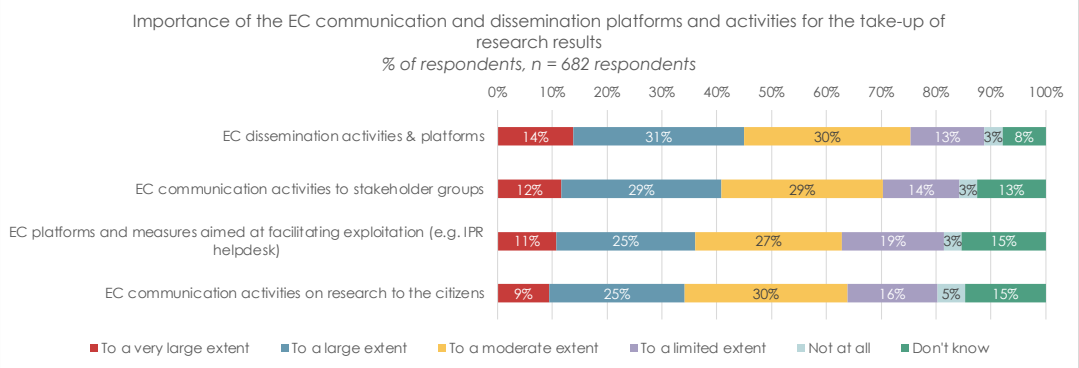
Next to a strategic use of the instruments, several case studies emphasised the importance of a **holistic portfolio management**. The case study on the FSTPs showed the importance of the EC coordination of the project cluster based on a clear vision on its purpose within the NGI intervention area. The case study on 'Earth Observation R&I in supporting Copernicus market uptake' highlighted the importance of synergies between individual projects for the joint attainment of the desired effects. The importance of an integrated approach, across the H2020 pillars, is one of the lessons learned from the case study on 'Access to critical raw materials'. Along a similar line, the case study on 'digital platforms for manufacturing' demonstrated the importance of a strong cluster approach, i.e. a high level of collaboration and exchange of experience between similar projects within the LEIT programme, beyond the 'silo' of the specific intervention area. The clustering approach also emerged as critical in the case study on 'safety concerns regarding the advancement of nanotechnologies'. It not only facilitated interaction between players in the field of nano-safety and nanotechnology, but the 'critical mass' that it created also helped to gain international visibility for further collaboration which was deemed necessary to bring the community forward. The case study focusing on the 'evolution of EGNOS and Galileo' emphasised the critical role of institutional cooperation between the EC, JRC, the European Union Agency for the Space Programme (EUSPA), and the European Space Agency (ESA) in steering the project directions and coordinating their technological needs to ensure that the design of the Galileo systems would be scientifically relevant. The importance of such cooperation can also be seen in the case study focusing on the 'contribution of LEIT ICT calls to the green transition', where DG CNECT cooperated with DG ENV to broaden the actors amd sectors targeted, thus furthering the alignment between R&I and environmental policy. Interviewees highlighted the important role of the CSA instruments, especially in relation to the non-technological aspects of innovation and cross-cutting issues. Representatives of partnerships, however, thought the division of labour between the CSA projects and partnerships was unclear at times, creating overlaps in their activities.

Closely related to the concept of portfolio management is the concern in the research communities that the **FP funding's balance** of close-to-industry R&D and more fundamental research (in the field of enabling technologies) might get lost. This was in the context of the trend showing decreasing funding shares for 'standard' collaborative RIA projects in the LEIT NMBP, and especially the LEIT ICT programmes (see Section 5.1.3, above). Researchers highlighted the importance of mid-level TRL research for capacity-building in view of longer-term needs ("re-filling the innovation pipeline") and the risk of greater decoupling of these two strands of research in the field of LEIT R&I. This trend towards lower funding shares for lower TRLs (2-4) was also flagged in the H2020 interim evaluation.

Knowledge sharing and information

As mentioned in Section 5.1.6, above, stakeholders responding to our survey appreciated and attributed a high level of importance to the EC dissemination activities and platforms as well as the EC communication activities to stakeholder groups. (Figure 34). Stakeholder opinions were more divided on the importance of platforms and measures such as the IPR helpdesks, digital marketplaces, and IP boosters.

Figure 34 Stakeholder opinion on the EC platforms and services for valorisations



Source: Study survey of H2020 LEIT applicants/participants, successful applicants. Q: In your opinion, to what extent are the following tools, instruments, and EC services important to facilitate the take-up of research findings for innovation?

Interviewees highlighted the importance of knowledge sharing opportunities and platforms, addressing actors beyond the participants in LEIT-funded projects. They also considered, however, that dissemination activities should go beyond the project results. The topic was specifically highlighted in

the context of the circularity contributions of process industries and advanced materials. While outcomes of the projects have not yet reached the market, a broad range of effects can already be observed both from a technological and non-technological perspective. Next to scientific and technical progress, knowledge about favourable business models, holistic sustainable analysis and non-technical barriers have all been accumulated. The challenge will be to ensure that the knowledge gathered by the project participants and stakeholders, currently mainly disseminated bottom-up within the consortium, can effectively benefit a wider audience.

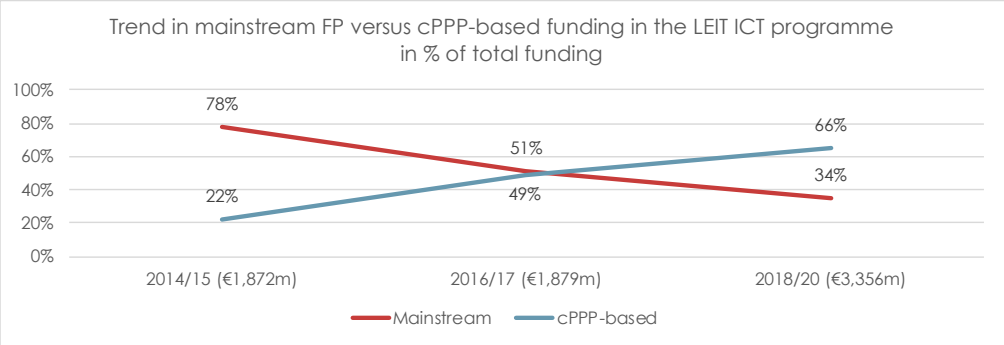
Evidence reported in Section 6.2, above, shows the LEIT programmes' excellent performance in the field of open access as well as in outreach activities, especially online news and social media. Nevertheless, in many cases interviewees considered a more professional approach would be desirable, which might require a more centralised system.

The role of public-private partnerships in the LEIT ICT and NMBP programmes

Funding data show the growing importance of the cPPPs in the portfolio of the LEIT NMBP and LEIT ICT programmes. In the latter, the projects based on the six cPPP[115] SRIAs accounted for 50% of the total funding (or €2.9bn), on par with the funding of 'mainstream FP' projects. The trend over time shows a shift in the funding shares for these two funding streams. The budget share dedicated to cPPP-based projects increased from 22% in 2014/2015 to 66% in 2018/2020 (Figure 35, below).

In the LEIT NMBP programme, cPPP-based projects[116] accounted for 35% of the total funding (or €1.3bn), concentrated in the Manufacturing and Processing Technology intervention area where they accounted for 97% of the total funding. The trend therefore mirrors the increasing focus in the NMBP programme on this intervention area. The funding share increased from 35% (or €0.90bn) in 2014/2015 to 40% or €1.6bn in 2018-2020.

Figure 35 Trend in the mainstream FP versus cPPP-based research in the LEIT ICT programme



Source: Technopolis Group, based on CORDA data (15/11/2021)

Typically, the PPPs in the LEIT programmes aim to address capacity failures by strengthening capability in key technology areas where Europe's competitive (or leading) position is challenged at global level. Quite obviously, public-private partnerships are inherently driven by industry needs, in line with the rationale for setting these initiatives up. Inevitably, their SRIAs and roadmaps are primarily shaped by industry interests/needs, and therefore focused on technologies and sectors that present potential for economic benefits in the near future, i.e. where the EU demonstrates globally competitive strengths.

The strong reliance on these partnerships raises some concerns in terms of the directionality of the funding available for research in specific technological fields. An example is the field of KDTs (micro- and nano-electronics and components/systems) where interviewees saw an issue especially in terms of gaps in research at the TRL4/5 level. Most of the funding in this field (about 70%) is channelled through the JU ECSEL rather than the 'mainstream FP' research.[117] The JU ECSEL dedicated 35% of its budget to the funding of RIA projects; in the mainstream FP, they accounted for about 50%. The funding

[115] cPPP Photonics, cPPP Big Data, cPPP 5G, cPPP Robotics, cPPP FoF, and cPPP Cybersecurity.
[116] Based on the cPPP FoF and cPPP SPIRE SRIAs.
[117] Jointly, the FP and the ECSEL funded projects for a total of €1,734m. The 'mainstream' FP projects accounted for €578m or 33%, the JU ECSEL funded projects for a total of €1,157m or 67%.

priorities in these two funding streams, combined with the imbalance in budgets available, implied that only about 20% of the total funding was dedicated to RIA projects 'steered' by the FP.

The priority setting, horizon scanning and forecasting capability of PPPs are essential to provide the relevant directionality and address shortcomings. In this context, the Study on the relevance and internal coherence of Horizon 2020 and its policy mix[118] considered the roadmapping exercises undertaken through PPPs as an enabler and pathway towards a mostly positive near-term future. Interviewees felt the roadmapping exercise could be strengthened by adopting more advanced scenario-based approaches, combining elements of (shorter term) roadmapping for planning purposes and (longer term) scenarios including **horizon scanning exercises** to better address long-term strategic objectives.

6.3.3. Directionality and the creation of societal value

The data analytics reported in Section 6.2.3, above, showed the significant contribution of H2020 and the LEIT programmes to the sustainable development and climate policy priorities as well as to a 'human-centric technological development and industry' and a 'safe, secure and geopolitically resilient society'.

Directionality towards a digital and sustainable industry, reflecting the development of the Industry 5.0 paradigm, has been increasing over time, in the FP bi-annual work programmes and specific calls as well as in the partnership SRIAs. Several case studies illustrated the LEIT programmes' achievement from this perspective, including the 'contribution of LEIT ICT calls to green transition'. Interviewees referred to regulations such as REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) as important drivers for industry to embrace the sustainable development goals.

The Study on the Focus Areas[119] in the WP2018-2020 considered the LEIT programmes' economic and technological focus as central. Primary goals were predominantly economy related. On a more general level, the 2021 ESIR policy brief considered that the Industry 4.0 paradigm, as it was conceived, was structurally aligned with the optimisation of business models and economic thinking. The High-Level Expert Group highlighted the need for a move towards 'Industry 5.0', "demanding attention to the wellbeing of workers, the need for social inclusion and the adoption of technologies that do not substitute, but rather complement human capabilities whenever possible".[120]

Next to the focus on sustainable development, the human-centred approach to innovation and the fostering of responsible R&I were important concepts in the H2020 LEIT ICT and NMBP work programmes, including non-technological aspects (i.e. addressing skills and training needs necessary for the exploitation of innovation.), and the broader ethical development of digital and industrial technologies (e.g. safe-and-sustainable-by-design, do-not-harm principle). The data analytics reported in Section 6.2.3, above, highlight the effectiveness of especially the activities in the LEIT ICT programme, confirmed also in interviews – for example, with actors involved in the Big Data cPPP. However, there appears to have been some underestimation of the human aspect to the behavioural change required. Our analysis of the LEIT ICT project portfolio showed that only 313 projects included an integration of Social Sciences and Humanities expertise. In line with other studies, the Focus Areas Study highlighted the importance of involving the social sciences and humanities to enhance the programmes' capacity for creating the conditions for change – among citizens and industry alike. Interviewees active in the field of manufacturing technologies nevertheless considered that there was a funding gap related to topics addressing human aspects also beside/beyond robotics and that this theme should be reinforced. They also saw the need for more societal/user participation via co-creation processes in this context.

7. Coherence

This chapter reports on 'coherence' as an evaluation criterion, and builds on the analysis carried out in two back-to-back studies focusing on the H2020 internal and external coherence, as requested by the

[118] Daimer S., Seus S., Afghani N. Wang A., Kroll H., Howoldt A., (2022) Evaluation Study on the relevance and internal coherence of Horizon 2020 and its policy mix. Interim report 2. Fraunhofer Institute for Systems and Innovation Research ISI, Technopolis Group, Austrian Institute of Technology, 4front.
[119] EC (2021) Opportunities and Challenges in Targeted Funding of Research and Innovation: Lessons learnt from the Horizon 2020 Focus Areas and implications for Horizon Europe Missions, CWTS, Technopolis Group, European Commission, DG RTD.
[120] EC (2021) Industry 5.0: A Transformative Vision for Europe, ESIR Policy Brief No.3, Expert group on the economic and societal impact of research and innovation (ESIR).

ToR. Where possible, findings of the two studies are complemented and supported by specific desk research, interviews, and data analysis.

Section 7.1 covers the 'internal' coherence dimension, within LEIT programme part and with other H2020 programme parts, as well as the coherence among partnerships and between partnerships and the FP activities in this area. Section 7.2 covers the 'external' coherence dimension, i.e. with programmes serving similar objectives at European, national, and regional levels as well as the positioning of the FP within the overall R&I landscape.

7.1. Internal coherence

7.1.1. In and between FP programme parts

Reflecting technological developments as well as the drive towards cross-fertilisation of the enabling technologies, the LEIT programmes created significant interconnections between the various programmes and their cPPPs. Examples can be found in the LEIT ICT programme between the JU ECSEL and the cPPP robotics, between the Artificial Intelligence intervention area and the cPPP Robotics, and between the cPPP Big Data and the cPPP FoF. In the LEIT NMBP, synergies between the nanotech and materials areas led to an integration of both areas under the 'advanced materials' denomination. Connections between the intervention areas within the LEIT Space programme and between the LEIT Space and the LEIT ICT and NMBP appeared weaker. The Space programme stood out for the strong differences among its intervention areas, covering a diverse set of industry sectors, and its rather limited integration in the digitalisation and industrialisation discourse. There was, however, greater alignment observed in the last programming period, thanks largely to the development of downstream applications produced by the European Global Navigation Satellite System (EGNSS).

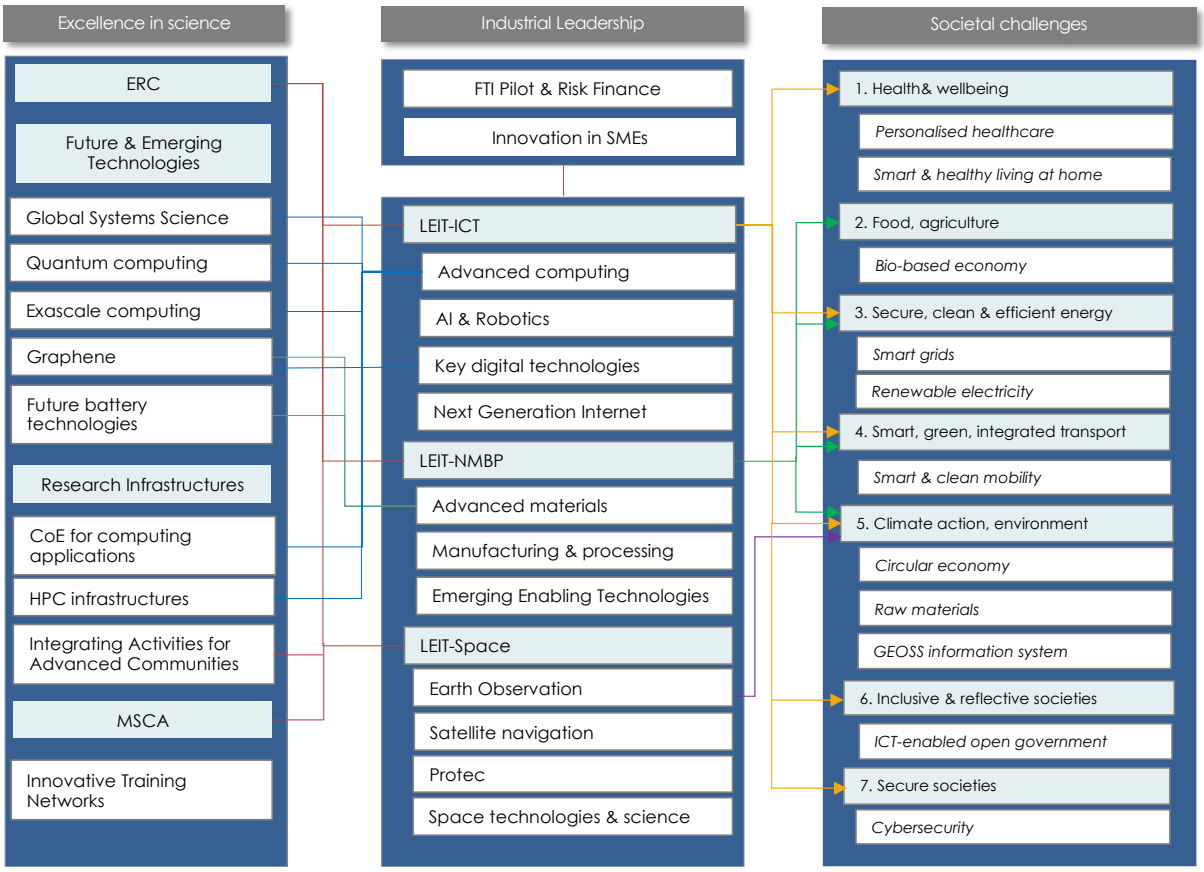
From a programme design perspective, our analysis showed that the LEIT programmes created strong downstream synergies with the Societal Challenges (SC) pillar and especially in the case of the LEIT ICT programme, upstream with the Excellence Science pillar (e.g. FET quantum computing, Graphene flagship, HPC) (Figure 36). The focus was especially on synergies with application-specific downstream research in the Societal Challenges.

Between the LEIT NMBP and SC5, the shift of funding for research on raw materials is regarded positively for the creation of a critical mass in funding and transfer to industrial upscaling. However, interviewees highlighted that fundamental research topics and cross-sectional topics (e.g. materials and modelling, functional materials, etc.) were less pronounced and not covered equally under SC5 as they were under the NMBP programmes.

The findings on the industry actors' participation patterns (see Section 6.3.1, above) highlight the importance of the 'bottom-up' coherence phenomenon as an (unstructured) means for coordinating FP-funded research and integratimg communities. 'Bottom-up' coherence appears to have taken on increasing importance also in the LEIT NMBP and Space programmes, as evidenced by their interconnections with the more fundamental research in the H2020 Pillar I. Interviewees mentioned an increasing and close-to-unique reliance on the expertise and cross-participation by individual organisations in the field, most often Higher Education institutions. This also reflected the observation in the H2020 Interim Evaluation[121] of an increasing disconnection between the NMBP programme and the Science pillar.

[121] SWD(2017) 221 final, Interim evaluation of Horizon 2020, Annex 2, p.342

Figure 36 Synergies between programmes in the three H2020 pillars



Notes: Upstream synergies are mapped in blue for the LEIT ICT programme, in red for NMBP, and in red for all programmes (no direct linkages for Space where detected). Downstream synergies are mapped in yellow for ICT, green for NMBP, and purple for Space.

Source: Technopolis Group, 2022

7.1.2. Coherence among partnerships and between partnerships and H2020

Considerations on the coherence among partnerships need to take into account the differences between these initiatives in terms of their typology and rationale, i.e. distinguishing between the predominantly industry-led PPPs and the policy-oriented public-to-public partnerships (P2P), as well as their function in the EU R&I system and scope of activity. Typically, partnerships such as the cPPP FoF and cPPP SPIRE, for example, are 'vertical' and focus on the needs and development of a specific application area, be it industrial or societal, while 'horizontal' partnerships such as the ECSEL JU or the Photonics cPPP are 'cross-modal' and focus on the development of technologies, methods and resources/materials that will be of use to multiple priority areas. Meanwhile, the EIT KICs have their focus on 'knowledge triangle' activities and needs. The Digitising European Industry Working Group on Digital Industrial Platforms[122] emphasised the importance of the interconnection between horizontal partnerships and with other industry-oriented vertical (application-oriented) partnerships and clusters.

Collaboration mechanisms aimed at the creation of **synergies between the partnerships** were increasingly seen under H2020, especially as a component of the process for defining the SRIAs. Targeted joint consultations and workshops for the co-development of SRIAs were increasingly organised between partnerships, also fostering the integration of vertical industries in the partnerships' priority setting (e.g. joint workshops on digital health involving ECSEL and IMI2, and between FoF, SPIRE and EeB cPPPs on how to jointly tackle global industrial challenges). The Photonics cPPPs also set up working groups with different focus areas (e.g. manufacturing, health, climate, space, etc.). Other initiatives were aimed at fostering horizontal collaboration between the private sides of European partnerships (covering both research and industry), to elaborate joint recommendations and contribute

[122] EC (2017) Digitising European Industry Working Group on Digital Industrial Platforms, Final version.

to partnerships' SRIAs and H2020 work programmes (e.g. Transcontinuum initiative). Joint calls were lauched, for example, across the EIT KICs.

Interviewees attributed signifcant importance to ensuring coherence between the partnerships' SRIAs and the **H2020 programmes.** There was consensus among interviewees that strong and transparent collaboration between the EC and the PPPs was critical for the partnerships to deliver added value. In general, partnerships report good cooperation with the EC especially during the agenda-setting process. Nevertheless, reflecting the conclusions in the H2020 mid-term review of the cPPPs, interviewees saw the need for more formal mechanisms to align the roadmapping exercises undertaken by the PPPs with the Work Programmes and stated that a more transparent and better-coordinated process for the translation of the SRIAs into call topics with a clear timetable would ensure that time-critical priorities, aligned with stakeholders' needs, can be fully implemented.

Interviewees also highlighted the increasing complexity from a partnership governance perspective. They pointed out that the expectation of an increased use of joint calls among the partnerships risks requiring *multiple* bi-lateral or multi-lateral SRIA co-creation processes for an individual partnership to provide systematic input for the Work Programmes. They recommended the establishment of a dedicated governance platform for the coordination of PPP input, to facilitate this process. On a similar line, the EC study on the Coherence and Synergies of Candidate European Partnerships[123] noted that collaboration between partnerships across domains (e.g. 'horizontal' ICT partnerships with 'vertical' application areas) would require dedicated structures to create alignment with the cluster approach in Horizon Europe.

7.2. External coherence

7.2.1. External coherence of the FP with other EU, national, regional, and international programmes

This section builds predominantly upon the analysis of the back-to-back study on external coherence and synergies of Horizon 2020.[124] It focuses on the various forms of coordination that aim to increase the contribution of the FP to the Digital and Industrial Transition.

With other EU programmes serving similar objectives

Coherence with other EU programmes serving similar objectives was embedded in the design of the LEIT programme part. Examples of **complementarities by design** can be found between the LEIT ICT programme and the Connecting Europe Facility (CEF) which only focuses on the deployment of technology and sufficiently mature projects that proved their feasibility in tests. In the field of space, LEIT Space shows built-in complementarities with the Copernicus and Galileo programmes. In this regard, the COM-ESA-EDA Joint Task Force, which aims to ensure that Europe can rely on a technical and industrial capacity for accessing space, and particularly the manufacturing of satellites and launchers, played an important role. For instance, their actions formed the basis for the Work Programme of LEIT Space Technology and Science.

The LEIT programme also showed complementarity with the European Fund for Strategic Investment (EFSI). The above-mentioned Evaluation of the H2020 External Coherence indicated that EFSI compensated for the EU's venture capital gap by providing the necessary financial support for more commercial, risky and close-to-market endeavours in similar activity lines as the LEIT ICT and NMBP programmes, and supporting the deployment of ICT infrastructure (i.e. broadband). Similarly, the report found complementarities with the European Structural and Investment Funds (ESIF) which provides support for the digitisation of companies. While complementary (in the sense that ESIF allows for consecutive funding with the LEIT programme part), the report noted that the different timeframes of the programmes often don't match, and limited evidence of exploitation of H2020 project results by industry for subsequent projects could be found.

The report findings show a limited and non-systematic use of cross-programme synergies at EU level in the context of the public-private partnerships. The use of Cohesion Funds as a funding source for national co-financing of tripartite model JUs such as ECSEL was limited under H2020 (0.6% of the total ECSEL budget) mainly due to legal and administrative barriers such as state aid rules. ECSEL has also established collaborations with the EUREKA cluster since FP7 and continued their coordination under

[123] EC (2020) Study on the coherence and synergies of candidate European Partnerships under Horizon Europe, DG RTD, 2020.
[124] EC (2023) Evaluation Study on the external coherence and synergies of Horizon 2020 within the European research and innovation support system, DG RTD.

H2020. More recently, the IPCEI on Microelectronics (approved in 2018) has been established in coordination with the ECSEL JU, as a vehicle to bring ECSEL results to the market and close the gaps in competencies and production capacities in critical areas.

With relevant national or regional initiatives

Partnerships also play a key role in strengthening the alignment between H2020 and national programmes and regional Smart Specialisation Strategies (S3). This is the primary objective of **ERA-NETs**, which foster the development and strengthened coordination of national and regional research programmes. The ERA-Net Cofund provides top-up funding for single joint calls for transnational research and innovation in selected areas of relevance to Horizon 2020, and led by Member States. They aim to leverage national funding dedicated to R&I agendas, in line with the H2020 priorities. Similarly, when considering the two JUs under the LEIT programme part, the tripartite model of governance and funding helps to increase synergies at national level.

Other PPPs organised joint activities by teaming up with Member States and regions to align their strategies with regional S3s. For instance, interviewees reported that the Photonics cPPP triggered joint funding activities between the PPP, Member States and regions (e.g. in the ERANET Cofund), more than 15 regions are involved in the Photonics S3 initiative, and planned the creation of a formal 'alliance of European regional clusters' with distinctive industrial and/or scientific strengths in photonics.

7.2.2. Potential measures to improve coherence with other initiatives

To improve coherence, a key element underlined in the above-mentioned H2020 External Coherence study is to increase the navigability of the R&I system. The role of intermediaries from this perspective should be further increased. Strategic alignment across programmes at EU level with dedicated governance structures is a pre-requisite to enable synergies. Partnerships could be key contributors to that process through the development of their SRIAs and dedicated dissemination and exploitation strategies. Partnerships can also play a key role to provide support for their members and all partnership-funded beneficiaries to participate in other EU programmes and obtain complementary sources of funding to foster the uptake of collective results. DIHs and EDIHs play an important guiding role, together with initiatives such as the European Enterprise Network and the European Cluster Collaboration Platform. They support networking which is an important element to navigate the R&I support system, linking companies with stakeholders who have more experience or links with successful consortia.

8. EU added value

This chapter reports on the evaluation criterion of 'EU added value' and the topics of investigation under each evaluation question. Section 8.1 covers the qualities and characteristics of the Framework Programme in terms of input, output and behavioural additionality. Section 8.2 specifically covers the value resulting from partnerships contributing to the Digital and Industrial Transition. Section 8.3 covers the EU added value of FP activities supporting the DIT.

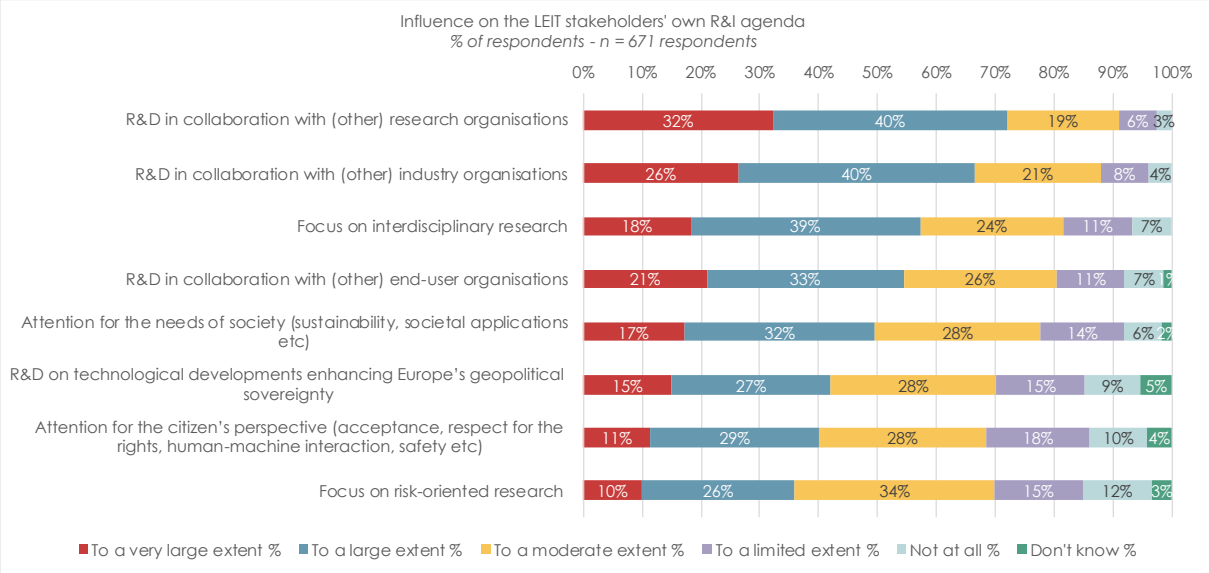
8.1. Input, output and behavioural additionality of the FP

Statements collected from survey respondents who submitted high-quality proposals but did not get funded show what should be regarded as high 'input additionality' in the quest for EU funding under the H2020 LEIT programme compared to other sources. In the absence of H2020 funding from the LEIT programme part, about 25% of survey respondents declared having abandoned the research idea and about 70% resubmitted it under another call or programme, most often at the EU rather than at national or regional levels (60%). When respondents declared having implemented their project either through national funding or through their own internal funding, only one in five declared that they could implement their project as originally planned. For most of the respondents (75%) it implied a reduction in scale or ambition.

The evidence collected through the survey also shows a high level of 'behavioural additionality' among participants in the LEIT programmes (Figure 37). For more than half of the survey respondents, their participation led to another approach to the research process and influenced their own R&I agenda. In about 70% of cases EU funding through LEIT influenced the collaboration patterns with both industry and research. In about 55% of cases, LEIT fostered interdisciplinary research, and stronger collaboration in R&D with end-user organisations. Based on those survey responses, the influence of

the LEIT programme on how much attention citizens' perspectives received during the projects (e.g. human-centric R&I, acceptance, respect for human rights) was more limited (40% of respondents). Comparatively, the LEIT programme's influence on inducing more risk-oriented research in LEIT stakeholders' own R&I agendas was also seen as limited (35% of respondents).

Figure 37 Influence of EU funding on the LEIT stakeholders own R&I agenda



Source: Study survey of H2020 LEIT applicants/participants

8.2. EU added value of the partnerships

The LEIT partnerships under H2020 addressed systemic and transition failures that could not be addressed by national funding, and they showed a high level of 'input and scale additionality'. They successfully mobilised significant private and public investments for the development of ambitious research, and new technologies of strategic interest to Europe, beyond the potential of single countries on their own[125]. The LEIT PPPs are key to targeting strategic dependencies in key technology areas for Europe, reinforcing the EU's competitiveness, European technological leadership and open strategic autonomy, and contributing to the Digital and Industrial Transition.

The most important contribution is in developing long-lasting knowledge ecosystems across different technological areas and sectors and across countries covering whole value chains. Their long-term vision is agreed and committed to by the major strategic public and private stakeholders in the relevant sectors, which were previously either competing or totally unrelated. Both cPPPs and JUs offered important opportunities to industry and Research Organisations to build long-lasting networks and ecosystems through participating in partnership activities, and by working together in projects, pilot lines and other types of instruments. According to interviews, both JUs and cPPPs went far beyond a funding function. The partnerships created a place to meet and discuss with European partners, competitors and other stakeholders who often lack such a structured channel for regular interactions.

At the coordination level, they contributed to developing a common vision and strategy among the leading players in their areas, tailored to industry while anticipating end-users' needs. The concrete cooperation between public and private parties through PPPs improve their understanding of each other's goals and ways of operating, thereby creating a strong basis for future cooperation as long-lasting effects beyond the project funding timeframe.

The partnerships, and especially P2Ps, sought to enable policy coordination at the EU, national and regional level. However, a recent JRC study[126] noted that the actual transfer of knowledge from EU to national and regional actors appeared to be rather limited. Here, it was concluced that PPPs, with their network creation capacity, would be an important instrument to better enable this transfer.

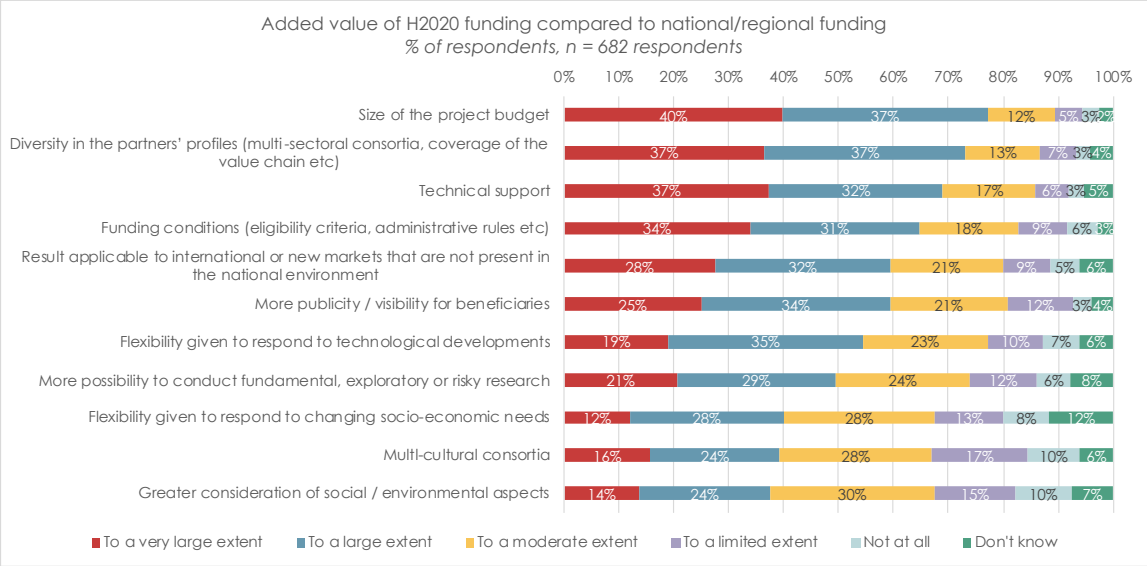
[125] Digitising European Industry Working Group on Future Partnerships, Report Version 1.0 March 2018.
[126] Haegeman, K., Arregui Pabollet, E., Harrap, N., Horbaczewska, K., Torrecillas Caro, M. and Valero Boned, S. (2019) Joint Undertakings: analysis of collaboration mechanisms with ESI Funds in an S3 context, EUR 29707 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-01486-7, doi:10.2760/000996, JRC116094.

8.3. EU added value of the FP to support the Digital and Industrial Transition

The EU added value of the FP to support the Digital and Industrial Transition is closely linked to the relevance of the intervention (i.e. the needs the programmes aims to address – Section 4.1.1) and the external coherence of the programme (i.e. the relative positioning of the FP in the European research and innovation system – Section 7.2.2). From this perspective, as mentioned in both sections, H2020 is the sole EU programme supporting mainly transnational R&I activities and networks, and which provides support across entire R&I value chains and innovation cycles.

Survey respondents indicated that the EU added value of the LEIT programmes goes beyond the topics related to funding (Figure 38). LEIT stakeholders also highlighted the importance of the quality of the network, in particular the diversity of the partners' profiles with multi-sectoral consortia, and/or covering the whole value chain (74%). Similarly, access to technical support from the best performer (69%), access to new markets that are out of reach in the national environment (60%), and the prestige signalled to future customers (59%) were reported as key elements highlighting the importance of conducting research at the European level.

Figure 38 Added value of H2020 funding compared to national/regional funding



Source: Study survey of H2020 LEIT applicants/participants

9. Key findings, conclusions, and suggestions for improvement

9.1. Summary of the key findings on the performance of the LEIT programme part

Relevance

The objectives of the LEIT programmes, as they were translated into the focus of the calls and the use of action types and funding instruments, were highly relevant to overcome the scientific and technological challenges and long-standing structural weaknesses that hinder a stronger EU global competitive positioning, while tackling the societal challenges that Europe and the world were facing. They were also in line with the stakeholder needs.

The flexibility and responsiveness to the changing (policy) needs and developments during the FP was for all LEIT programmes apparent in the shift in focus from a challenge-based perspective in the first half of H2020, with industrial competitiveness and job growth as the main targets, to the impact-based perspective in the second half of H2020 and especially, the third Work Programme.

Efficiency

To enhance the efficiency of its **administration and management processes**, the EC increasingly adopted new management modes. There was a considerable and increasing use of the cascade funding

model (or Financial Support to Third Parties), in multiple types of actions and instruments. An assessment of these measures was inhibited by the lack of data.

The simplification measures instigated under H2020 were considered to be highly effective. Stakeholders especially appreciated the strong improvement in the time-to-grant. Meanwhile, the transparency of the funding decisions and completeness of the evaluation reports are ongoing and lasting issues.

The **funding distribution** was marked by the trend towards a decrease in the funding of collaborative RIAs, the funding share of Higher Education Institutions, and the funding of SMEs (partly due to the discontinuation of the SME Instrument after the second Work Programme, replaced by the EIC Pilot scheme). It also implied an increase in the funding of collaborative research IAs and technology infrastructures, the funding share of the Research Organisations, and the average project budgets and size (for all types of instruments). Overall, collaborative research remained at the core of the LEIT funding. To be noted is also the low funding shares of organisations located in the EU13 Member States (5%) and the very limited participation by Third Country organisations (2% of all participations). The LEIT programme part had an overall success rate of 9% – but a success rate of 15% when not taking into account the new SME Instrument, which had a particularly low success rate. This rate is only slightly lower than the 17% under FP7 (for the related programmes).

The trend in funding distribution implied an increasing complexity of **project management**, requiring considerable expertise and resources (both financial and human) within the organisation taking up the project coordination role.

The **H2020 monitoring and evaluation system** presented specific strengths in monitoring the FP's progress from an operational perspective. It showed limited capacity for a more fine-grained assessment of knowledge and innovation dynamics from a transformative R&I policy perspective and the (longer-term) spill-over effects on the EU R&I system at large.

Effectiveness

There are important limits to our assessment of H2020's effectiveness. The timing of the evaluation means that effects can be measured for about 60% of the LEIT projects, accounting for 30% of the LEIT funding.

The LEIT programme is **on track towards reaching its scientific and technological objectives.** Data showed that funding in the LEIT programme part had a clear reinforcement effect on the R&I capacity, ensuring research excellence and knowledge sharing, including through research-industry co-publications. The effectiveness of the funding of technology infrastructures cannot (yet) be assessed due to lack of data on the FSTP model and the fact that most of these projects had not concluded when the study commenced). The LEIT also successfully addressed systemic failures in the EU R&I system by integrating research communities and creating cross-sectoral knowledge ecosystems. The effectiveness of the funding of technology infrastructures cannot yet be assessed. It fostered the cross-fertilisation of technologies which, however, has not yet led to enhanced cross-disciplinarity in research, limiting the potential for scientific impact.

The LEIT programme has **provided the foundations for future impacts in the innovation and economic sphere**. Indicators suggest that participation in the LEIT programmes might have already had a positive effect on the industry participants' productivity and profitability. It led to the production of good ideas where the participants see high potential. In general, many of the innovations are still in their infant stage, just emerging, or indeed the market is immature or non-existent. Most have not been protected by IP rights nor broadly diffused, as there is still some way to go before full commercialisation is possible. As an indication of the attainment of breakthrough technological developments, about 10% of the SMEs participating in H2020 projects were successful in raising private funding after their H2020 activities (reaching a total of €9.36bn), mainly in the form of venture capital and equity funding. The lack of benchmark data does not allow us to assess the adequacy of this performance. Nevertheless, the low activity in the valorisation of the research results is a cause of concern.

The LEIT programmes appear to have **responded positively to their objectives in the societal sphere**. The directionality of the LEIT programmes, combined with the context of the regulatory environment, allowed for the creation of research results that laid the ground for a more sustainable, human-centred, and responsible innovation and industry environment. The LEIT programmes showed

strong performance in providing input to policymaking (policy-related citations) and in their outreach to the broader community and society, by means of the projects' online dissemination efforts and open access to their publications.

Enabling factors for the future attainment of the LEIT objectives include the **close alignment with stakeholder needs**, leading to organisations actively participating in different sectors across the programmes' intervention areas, facilitating the desired cross-sectoral collaboration, and enhancing understanding of user needs. The LEIT programmes appear *not* to have been in line with stakeholder needs in their focus and allocation of funding for the conduct of pre-standardisation research and international collaborations.

The choice of the policy instruments is an important step in the **programme design** process. The strategic use of the action types and funding instruments and the holistic portfolio management were important success factors in the programme implementation. Stakeholders also attributed high importance to the EC dissemination activities and platforms as well as the EC communication activities to facilitate the take-up of innovation.

The **directionality** of the research funded, based on the coordinated use of CSAs, the SRIAs of the public-private partnerships as well as input from industry associations and technological experts (and in the case of the LEIT Space, the collaboration with the ESA), ensured strong alignment with the needs of the targeted industry sectors and the policy objectives.

Coherence

The LEIT programme part showed a **good level of internal coherence** among the various sub-programmes and initiatives, including the partnerships. The only exceptions were the LEIT Space programme which demonstrated weaker connections between its different intervention areas and with LEIT ICT and NMBP programmes, and to an extent, the EIT KICs which appeared less integrated in the overall LEIT portfolio, at least from a formal perspective.

There were **strong downstream complementarities** with the Societal Challenges pillar and for the LEIT ICT programme, **upstream complementarities** with the Excellence Science pillar. In the LEIT NMBP and Space programmes, the creation of synergies was mostly relying on the expertise and cross-participation by individual organisations ('bottom-up coherence').

External coherence with national and regional funding programmes was facilitated by the public-to-public partnerships in the field of advanced materials and metrology, and in the field of Space technologies thanks to strong collaboration with the ESA and the creation of complementarities with the Copernicus and Gallileo programmes. Efforts to enhance collaboration and create synergies in the field of ICT and NMBP, by using the ESIF and other instruments, were hindered by a mismatching of the different programmes' timeframes.

EU added value

The LEIT programmes showed a **high level of 'additionality'** compared to other possible funding sources. The programme enabled a behavioural change towards more research-industry collaboration and greater attention on the Societal Challenges in the organisations' own research agenda.

The **European dimension** of the funded research was considered **critical** for the creation of multi-sectoral consortia, the cross-fertilisation of knowledge and knowledge exchange with the best performers in Europe, and the access to new markets that are out of reach in the national environment.

9.2. Conclusions and suggestions for improvement

In this chapter we draw our conclusions on the question that is at the core of this evaluation, i.e. the extent to which H2020 contributed to the Digital and Industrial Transitiosn – and how. After a brief introduction on the key concepts, we give an overview of the FP performance in contributing to the desired transitions, identify challenges, unintended effects, and emerging risks, and provide recommendations based on the lessons learned.

European R&I policy, the design of Horizon 2020 and particularly Horizon Europe was strongly influenced by the concept of **transformative R&I policy** with its aim to enable a transition towards a competitive, human-centric, resilient, and sustainable European ICT and manufacturing industry.

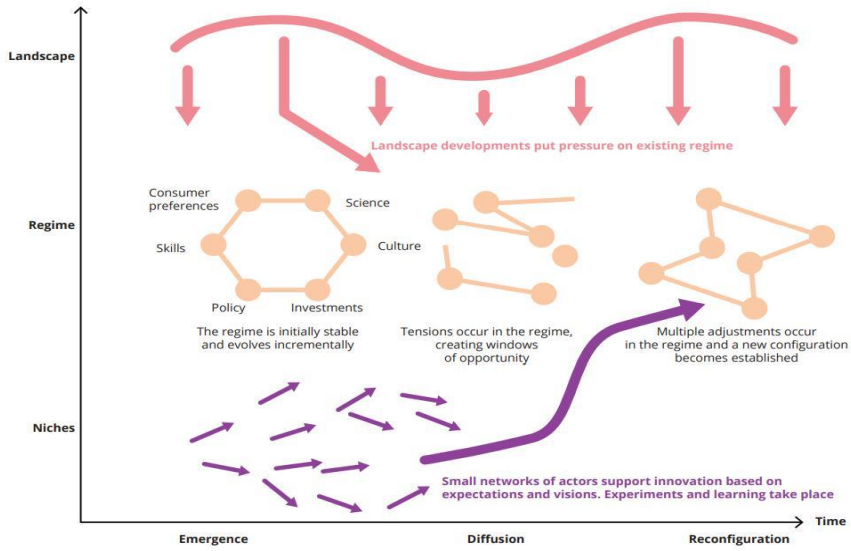
Industry 5.0[127] is the term coined by the EC that emphasises the social and environmental dimensions considered indispensable to systemic transformation. It highlights the need for the promotion of R&I to go beyond the gains that digitalisation and further automation could provide to companies in terms of efficiency and profit. The aim is also to support the development of solutions that render the production more sustainable, resilient, and competitive on a long-term basis, and which considers societal constraints.

The 'multi-level perspective' on **transitions** describes processes arising from the interplay of developments at three levels: regime, niche, and landscape (Figure 39).

The regime comprises the diverse factors that structure existing modes of producing and consuming. These include technologies, regulations, infrastructures, behaviours, and cultural norms, which have co-evolved in ways that hinder the emergence of alternative technologies, business models and social practices. Landscape developments include long-term megatrends (e.g. social, economic, environmental), or more sudden shocks (e.g. the recent COVID pandemic). Niches are protected spaces, such as R&D labs or demonstration projects, where entrepreneurs can experiment and develop radical innovations without direct exposure to market forces, consumer preferences, and so on. [128]

The specific role of public R&I policy is in driving change through a mix of instruments aimed at creating niche innovations with transformative potential, drive scaling, replication, and diffusion of innovation, and promoting a change in discourse (new shared vision, new ways of thinking), practical applications of new technologies, changing modes of policymaking, and new business practices in an ecosystem.

Figure 39 The multilevel perspective on sustainability transitions



Source: European Environment Agency, based on Geels (2002)

Responsiveness to landscape developments

The design of the LEIT programmes was highly relevant in responding to the pressures from the 'landscape' on European society in the economic and societal spheres. The shift in the second half of H2020 towards an impact-oriented perspective reflected the increasing sense of urgency to address the challenges at hand. Evidence showed that research conducted under the LEIT programmes facilitated the development of innovative solutions and applications in the field of healthcare, energy efficiency, smart agriculture, environmental protection, smart transport, safer internet services, etc. Scientific and innovation outputs of the funded research projects contributed to the key Sustainable Development

[127] The ESIR Expert Group specifies "'Industry 5.0' nests the Industry 4.0 approach in a broader context. The development is from a narrow and traditional focus on technology- or economic-enabled growth towards an enhanced focus on the circular economy and environmental dimensions as well as an inherently social dimension. See Dixson-Decleve, S. et al (2021) Industry 5.0: A Transformative Vision for Europe - Governing Systemic Transformations towards a Sustainable Industry, ESIR Policy Brief No.3, European Commission, DG RTD.

[128] European Environment Agency (2019) The European environment – state and outlook 2020, Knowledge for transition to a sustainable Europe.

Goals related to the EU's green and climate policy priorities as well as those directed at human-centric technological and industrial development, and a safe, secure, and geopolitically resilient society.

An area of weakness in the LEIT ICT and NMBP programmes was the **limited international collaboration.** This was partly due to the limited number of cooperation agreements with international funding bodies (lack of policy coordination) while also the broader geopolitical changes after 2017 and the rising strengths of competitive economies such as China, as well as the lack of interest (and in some cases, even reluctance) among industry actors.

Recommendation 1: *We recommend the EC foster international cooperation, especially focusing on (horizontal) lower TRL topics that are not (or not yet) at the core of the EU competitive advantage, in the industrial technology domain, where industrial partners are often hesitant to engage in internationalisation activities. This could be implemented by providing a guiding policy framework tailored to the specific thematic areas. Such a policy framework could cover the specific countries to consider based on specific criteria (e.g. added value in the domain, reciprocity, strategic autonomy, and other geopolitical aspects, etc.)*

We invite the EC to consider the suggestion made by the ESIR Group[129] "to reframe the quality of its leadership in the world" and direct the international cooperation efforts to research activities focused on the Industry 5.0 topics of new manufacturing, sustainability, ethics and a digital economy/society, fostering the creation of global standards and norms.

A topic for consideration in this context is the **strong industry influence** on the LEIT programmes design and the increasing influence of the public-private partnerships' strategic research and innovation agenda on the funding decisions, particularly in the case of the LEIT ICT and NMBP programmes. While the support for industry-led partnerships and their roadmaps was critical for the programmes' success, one should also consider that market forces tend to concentrate resources in areas of strength, where competitive advantages could be built. Bottom-up approaches in priority setting are often ineffective in directing resources towards industry's structural weaknesses. By design, the PPPs are strongly driven by economic interest (by virtue of the private-sector involvement), tend to focus on gaining or maintaining industry strengths, often pursue short(er)-term perspectives, and attribute limited importance to international collaboration and standardisation efforts.

Recommendation 2: *We recommend the EC maintain a strong policy coordination role and ensure its capacity to provide directionality in the instruments targeting critical technology areas by maintaining a research agenda alongside the partnerships' roadmaps.*

We invite the EC to make more extensive use of the CSA instrument for the creation of strategic intelligence and to enhance its strategic use of foresight and policy feedback, taking a longer-term and Industry 5.0-oriented perspective that goes beyond the horizon scanning of technological developments or trends. Improving the EC's internal processes to accelerate the absorption of those project results and feed into the policy and programming cycle in a timely manner is also essential.

Development of early innovations

The delivery of a protective space for the experimentation and development of innovation based on enabling technologies was at the core of the LEIT programme part under H2020, acting as a bridge between exploratory science under Pillar I and the development of applications addressing Societal Challenges under Pillar III.

The LEIT programmes fulfilled their task by funding **collaborative research** projects that provided the building blocks for further research and innovation, preparing the ground for scaling-up and replicating innovation to speed up the process, and by enhancing the availability of **technology infrastructures** throughout Europe that facilitated and accelerated the development of piloted, demonstrated, and tested research results.

Outcomes were research results of high scientific impact and technological breakthroughs that allowed for further private funding of high-tech SMEs. The focus on cross-fertilising the technologies and cross-sectoral research, in line with the stakeholder needs and leading to the involvement of actors in multiple value chains, enhanced the stakeholders' capacity to articulate user demands, and supported the

[129] Dixson-Decleve, S. et al (2021) Industry 5.0: A Transformative Vision for Europe – Governing Systemic Transformations towards a Sustainable Industry, ESIR Policy Brief No.3, European Commission, DG RTD.

creation of new knowledge ecosystems. Research was directed towards technological developments and innovations that fostered the creation of products, processes, and services that responded to societal needs and citizen concerns.

A corollary to the cross-fertilisation – and especially the cross-sectoral approach – was the **rising cost and complexity of the projects**, involving a high number of stakeholder organisations. Combined with the emphasis in the last phase of H2020 on the funding of high-cost, large-scale technology infrastructures, it also led to a more pronounced **concentration of the funding**.

Challenges emerging from these trends include lower interest among high-tech SMEs to participate in projects (due to the decrease in funding share dedicated to RIA projects), the difficulty many stakeholders confront when responding to calls with very high expectations/strict criteria (resulting in low proposal success rates), and high requirements set on project management in terms of expertise and availability of human resources. It risks creating 'winner takes all' dynamics and an enhanced path dependency, hindering a stronger participation among EU13 stakeholders, and in the context of the place-based technology infrastructures, some tension between the excellence and cohesion policy objectives.

Recommendation 3: *We recommend the EC consider the potential to reduce the project complexity by limiting the number of actors involved and value chains covered. Strengthened portfolio management, creating project chains or parallel-running projects coordinated by CSAs, might be a solution. Another option could be to adopt different evaluation criteria depending on project size, with larger projects needing to fulfil extra requirements to ensure the diversity of consortium members (e.g. EU13 participants, SSH dimension, sector representativeness, etc.).*

The importance of 'effectivess' and perceived urgency to generate 'impact' also appears to have led to an **enhanced focus on innovation**, to the detriment of the funding of more mid-stage research activities (R&I actions). Stakeholders see the risk of the balance between close-to-industry R&D and more fundamental research ("re-filling the innovation pipeline") getting lost, and an increasing decoupling of these two strands of research.

Taking a holistic perspective, the ESIR Group emphasised the need for public funding of both early- and mid-stage portfolios of actions that are "more effective in facilitating unexpected, intersectoral combinations and transformative options for large scale structural change". It also criticised the "Artificial and unhelpful separation between research and innovation (invention) and deployment (implementation)".[130] In this context, the weak connections between the LEIT NMBP and Space programmes and the exploratory research activities in the Excellence Science pillar are to be noted.

Recommendation 4: *We recommend the EC maintain a balanced approach to the funding of medium- and high-TRL research combined with increased cross-programme fluidity, facilitating ongoing capability building in view of longer-term needs while creating technological trajectories, and to ensure an optimal knowledge flow from early discovery to applications.*

We invite the EC to engage in stronger portfolio management, making strategic use of all action types and instruments, reflecting their specific function in the programme portfolio and depending on the needs in the EU R&I communities.

Seeing the enhanced focus on interdisciplinary research in the LEIT programmes, aimed at a cross-fertilisation of technologies, the **limited influence on the cross-disciplinary nature** of the (scientific) research results was a surprising outcome. The proposal evaluation and selection process may play a role in this context: as the 'Study on the proposal evaluation system for the EU R&I framework programme' stated, "Peer review–based proposal evaluation processes tend to be conservative, and there are indications this may apply in the case of H2020."[131]

In addition, a weakness of the LEIT programmes appears to be in the rather **low level of IPR applications** deriving from the research funded under the LEIT programmes, which hinders the ability to reap the benefits of these technological developments for strengthened EU competitiveness on the global scene. **There is a risk, however, for this to be underestimated due to the lack of data**. In

[130] Dixson-Decleve, S. et al (2021) Industry 5.0: A Transformative Vision for Europe - Governing Systemic Transformations towards a Sustainable Industry, ESIR Policy Brief No.3, European Commission, DG RTD.

[131] Rodriguez-Rincon, D. et al (2022) Study on the proposal evaluation system for the EU R&I framework programme, Rand Europe, a study for the European Commission, DG RTD.

addition, it was beyond the remit of this study to ascertain the extent to which this low level of IPR applications is due to a significant under-reporting, relates to disincentives in the funding instruments for IPR applications, or reflects the current state of technological advancement.

Recommendation 5: *We recommend the EC further investigate the extent to which the selection of H2020 evaluators and their profile, and/or the formulation of the evaluation criteria in the call descriptions effectively hinder the conduct of highly innovative, cross-disciplinary research in the LEIT programmes or whether other factors played a role.*

We also recommend the EC commission a study that collects information of IPR filings and registrations even several years after the end of the projects to collect information on post-project IPR filings. Such a study should also shed light on the question whether there are any disincentives (official) to reporting patent filings or trademark registrations that may partly explain the low numbers.

We invite the EC to boost incentives for the filing of patents or any other kind of IPR in future Framework Programmes. In this context it should be noted, though, that stakeholder opinions were very polarised with regards to the importance of IP-related services such as digital marketplaces and IP boosters.

Policy coordination of the regime

Policy coordination is of key importance in the context of an R&I policy aiming at transitions and transformational change in the entire EU R&I system. It is the main challenge in the transformative R&I policy implementation, requiring coordination across all levels of policymaking.

In the LEIT programmes, the frameworks for addressing this challenge were for the LEIT ICT and NMBP programme, the Digitising European Industry (DEI) initiative (launched in 2016), and for the LEIT Space programme, the EU Space Strategy and the coordination procedures in place among ESA, the European Defense Agency (EDA) and the EU Commission.

Policy coordination **within the LEIT programme part** allowed for the creation of significant synergies between the LEIT ICT and NMBP programmes. While connections with the LEIT Space were weaker, in the last programming period further synergies with the ICT area were found through the development of hubs and support to downstream applications produced by the European Global Navigation Satellite System (EGNSS).

Throughout all LEIT programmes, the use of CSAs that coordinate individual projects had the additional value of facilitating the creation of knowledge ecosystems, by tapping into the research activities in, for example, the pilot lines and industrial platforms.

Within the ICT and NMBP communities, the public-private partnerships played a critical role in strengthening knowledge ecosystems and integrating communities. The partnerships acted as intermediaries for the implementation of the programmes, next to the RTOs and university competence centres facilitating the creation of European technology infrastructures. RTO and university competence centres were also at the core of the place-based innovation initiatives, aimed at strengthening the local ecosystems.

Policy coordination with the **R&I funders in the EU Member States and regions** was more difficult to achieve and was hindered by multiple factors, including a lack in synchronisation of funding programmes. A case in point was the development of the Digital Innovation Hubs where contributions from the EU Member States were achieved only at a later stage of the initiative to set up and further develop a European DIH network.

A lesson to be learned is that the funding of place-based innovation initiatives, aimed at the strengthening of local ecosystems, in the context of a European *competitive* research funding programme, risks creating tension between 'excellence', represented by the FP and the 'cohesion objectives' of the European Research Area, with the former prevailing over the latter. The competitive dimension of the FP, with selection of the winning proposals based on excellence and delegated to evaluators, tends to imply the concentration of these initiatives in the more innovative, leading Member States and regions. Unless there is a framework agreement with the Member States, with a clear division of labour and investment, these initiatives risk deepening the **innovation divide** in Europe. Investment by the Member States also appear to be paramount for the sustainability of these initiatives.

In view of supporting the deepening of the ERA and while enhancing critical mass, public-private partnerships could play a stronger role to enable synergies, policy coordination and co-funding mechanisms at EU, national and regional levels. The creation of synergies with the Structural Funds is an 'untapped opportunity' especially for the cPPPs. While DG Regio plans to create a platform to support Member States from this perspective, it will also require clear and timely communication from the partnerships to feed into the national and regional programming.

The drive for the PPPs and P2Ps to create synergies across the partnerships and at different levels of policymaking, nevertheless, requires additional support and policy coordination at the central level. While such platforms and structures are currently being developed at the overall FP level, opportunities for more intensive knowledge and information sharing appear needed,

Recommendation 6: We recommend the EC support the partnerships in their endeavours to create more synergies by creating knowledge sharing arenas beyond the ones organised at FP level, specifically targeted at the LEIT-relevant horizontal and vertical partnerships.

As for the policy coordination of the **industry actors**, action is needed to address a certain resistance to change. The extent to which the FP has effectively succeeded in convincing industry to take up its societal mission – beyond the sustainable development and climate change aspects where the regulations act as a key incentive – is questionable. Current rather anecdotal evidence from the interviews and workshop shows that the human-centred innovation concept, emphasised in the 'Industry 5.0' focus on human progress and well-being, is perceived as a top-down policy objective unless there are clear economic incentives for its implementation. Most often, the technological and economic discourse prevails. The need for a cultural change is illustrated also by generally limited direct involvement of citizens or civil society actors and those with expertise in the Social Sciences and Humanities. A greater focus on change management and support for adoption processes is needed to achieve desired transformations.

Recommendation 7: We recommend the EC strengthens its role as an agent of change by increasing its focus on fostering behavioural change aimed at better endorsing human-centred innovation and resilience priorities among all actors in the EU R&I communities.

We invite the EC to ensure a more pronounced and wide-spread integration of Social Sciences and Humanities expertise in the FP portfolio, taking better account of the human aspects behind effective transformation. To do so, new approaches should be investigated, building on a stronger portfolio management and coordination role by the EC, to ensure the diffusion of SSH throughout the FP.

Throughout this evaluation, a number of issues emerged hindering the **capacity to assess the effectiveness** of the H2020 contribution to Digital and Industrial Transition **in all its dimensions**.

First, the timing of the evaluation implied that effects were measurable only for about 60% of the LEIT projects, accounting for 30% of the LEIT funding. The evaluation therefore can give only a partial view on the H2020 effectiveness – even in relation to the immediate to short-term project outputs and outcomes.

Second, the lack of data on the cascade funding model (FSTP), used in technology infrastructures and collaborative research projects alike, inevitably implied an underestimation of the effects reached by the LEIT ICT and NMBP programmes. Another issue is a potential distortion of the FP funding distribution over the stakeholder groups, from a geographical and type of stakeholder perspective (especially the SMEs and the Research Organisations). In addition, the increasing practice of applying this model (comparable to the innovation voucher model in the national funding practice) merits further consideration. While our case studies indicated the benefits of this model in lowering the entry barrier to FP funding for SMEs, the results and benefits for these 'Third Parties' and the wider effects on the local ecosystems are currently not visible nor can they even be estimated.

Third, the data made available on the EIT KICs did not allow for an analysis of the profile of the EIT KIC members and their level of integration in the FP activities. It hindered a more thorough analysis of the coherence between the EIT KICs and the FP, seeing that the coordination appears to have happened predominantly bottom-up, i.e. through the cross-participation of individual organisations. The EIT KICs also do not make the list of their members publicly available.

Last but not least, there is a clear need for the FP Monitoring and Evaluation System to enhance its capacity to assess FP effectiveness in the context of a transformative R&I policy, aiming at the creation of transitions. Next to the topics set out above, this includes: the need for improved categorisation of the instruments reflecting their function in supporting R&I (e.g. collaborative research versus place-based technology infrastructures) as well as the type of research (e.g. the blurred boundaries between RIA and IA in terms of TRL); the need to improve understanding on the creation and diffusion of innovation, currently relying close to exclusively on IPR data, the Innovation Radar estimating the 'market creation potential' of FP-funded projects being a useful exception, including the creation of knowledge ecosystems; and finally, the capacity to assess the FP effectiveness in creating (longer-term) spill-over effects to the broader R&I system.

Recommendation 8: *We recommend the EC enhance the FP Monitoring and Evaluation System by ensuring centralised data collection for the FSTP model, including the funding distributed to these 'external' Third Parties, the number and profile of the SMEs supported, and the results reached.*

We recommend the EC improve the availability of data on the EIT KIC beneficiaries, including on the KIC members and the actors involved in the KIC co-location centres.

We recommend the EC improve its capacity to capture and assess FP effectiveness in relation to its contributions to transitions and the transformation of EU industry and society at large – in terms of its short-, medium- and long-terms effects, and including the spill-over effects on the broader EU R&I system.

We recommend the EC undertake an ex-post impact assessment at least five years after the end of the programme to allow for a comprehensive evaluation of FP effectiveness and ensure lessons can be learned for further policymaking.

An **overall conclusion** is that the H2020 contributed to the Digital and Industrial Transition by responding to the changing landscape developments and supporting the development of breakthrough innovations. The high attention placed on the creation and strengthening of knowledge ecosystems, the development of infrastructures and pilot lines, and the improvement of framework conditions were critical from that perspective. The increased use of input from industry actors and technological experts in the programming process ensured a stronger alignment with the needs of the targeted industry sectors and end-users, setting the conditions towards genuine transformation.

A key area for improvement identified during the H2020 was in policy coordination with the Member States. This was addressed in later stages of the Framework Programme and has been emphasised in Horizon Europe. There remains a clear risk that the effectiveness of the LEIT programmes will be underestimated due to lack of data. There is a need for the FP Monitoring and Evaluation System to enhance its capacity to assess FP performance in the context of a transformative R&I policy. Lastly, in light of the timing issue – a large percentage of LEIT projects had not concluded their activities at commencement of the evaluation – a H2020 ex-post evaluation collecting longer-term data once all projects are concluded is needed to gain a full view of the Framework Programme's contributions to DIT.

APPENDIX A: DETAILS ON METHODOLOGY

A1 Database management and classifiers

A critical element of this evaluation, underlying the descriptive statistics in this report, was the creation of an **integrated relational database**. This database encompassed:

- The FP CORDA data – entailing
  - Data related to projects, participants, proposals, and applicants for the entire FP as well as the FP structural data (objectives, themes, topics, calls, etc) – which includes the data for the Joint Undertakings
  - Contact details of LEAR and PCOCO for the LEIT participants and unsuccessful applicants reaching above-threshold evaluation scores
  - Monitoring data related to outputs and policy / topic markers (relevance of topic lines, calls or projects for EC policies such as the Digital Agenda, Sustainable development etc)
- Data provided to us by the EC related to
  - The activities and participants in the ERANets, Art 185, and EIT KICs of relevance for this study
  - InnoRadar data
  - ORBIS/BVD data on NACE codes of LEIT participants

Next to setting the basis for the STI data analytics, this relational database established a reference for the identification of DIT-relevant projects beyond the LEIT programme, which was done during the inception phase. It also allowed for an overall state-of-play analysis in the inception phase (see the inception report) and a **detailed portfolio and composition analysis** at the LEIT thematic area, intervention area, and topic lines levels. The outcomes of these detailed analyses are integrated into the final report and its annexes.

A **consistent structuring of all data** provided allowed for concise reporting. A set of classifiers were defined and improved on an ongoing basis throughout these first months, tailored to the needs of this evaluation. The tables below gives an overview of the process.

Classifiers at project and proposal level

Classifier code	Description
DIT_FULL_RESEARCH AREA	All H2020 projects relevant for Digital and Industrial Transition that are subject for this evaluation. It excludes cPPP BBI and cPPP EEB projects and the cPPP Cybersecurity projects in the non-LEIT programmes, as requested by the EC because these projects/cPPPs are covered in other evaluations.
DIT_FULL_Intervention Area	Indication of the intervention areas as they are defined for the LEIT programmes (see below) that are relevant for specific projects/topics – where available/feasible.
DIT_LEIT_THEMATIC_AREA	Based on CORDA FP structural information (THEMA & CD_CALL_IDs); LEIT H2020 projects relevant for digital & industrial transitions that are subject for this evaluation. It excludes cPPP BBI and cPPP EEB projects and the cPPP Cybersecurity projects in the non-LEIT programmes, as requested by the EC because these projects/cPPPs are covered in other evaluations. The thematic areas are equivalent to the LEIT programmes.
DIT_LEIT_INTERVENTION_AREA	Subcategories of the LEIT Thematic areas.

Classifier code	Description
	For ICT and SPACE, they reflect the intervention area descriptions provided in the Horizon Europe WP 2021-22. For NMBP the intervention areas are the equivalent of the NMBP programmes (as defined in the CORDA codes THEMA). However, the Biotech programme that has been 'merged' with the Nanotech in 1 programme (Emerging Enabling Technologies), as agreed with the EC. The ManufProc intervention area covers also the cPPP FoF projects funded under the ICT programme.
DIT_INTERVENTION AREA TOPIC LINES_	Based on CORDA TOPIC/DIVISIONs descriptions. Subcategories of the LEIT intervention areas. Groups the research topics of the calls under common headings; the topic lines relating to cPPPs or JUs are listed separately.
DIT_PARTNERSHIPS	Based on CORDA CD_TOPIC, CD_DG, CD_ACTION_TYPE, CD_CALL_ID as well as Information in the CORDA Monitoring (policy) markers on specific cPPPs. Specific partnerships under which the projects were funded (JTIs), steered the funding through their Strategic Research Agenda's (cPPP), or projects focused on supporting ERA-NETs.
DIT_CAT_Mainstream	Based on DIT_Partnerships_Final. Distinguishes between the different funding streams Mainstream FP, cPPP-based projects, JU-managed projects and ERA-NETs.
DIT_INSTRUMENT	Based on CORDA CD_ACTION TYPES & topic/call indications of project focus (keywords: platform, hub, testing, testbed, pilot). Categorisation of projects based on the type of research activity and/or support provided. Projects based on/funded by partnerships are listed as cPPP, JU, ERA-NET Cofund.
DIT_ACTIONTYPE	Based on CORDA CD_ACTION TYPES. Broad categories of FP action types, without indication of the specific partnerships under which they were funded. Aggregation of ERC, MSCA and SME Instrument action types.
DIT_CAT_INSTRUMENT	Based on DIT_INSTRUMENT_FINAL & DIT_ACTION TYPE. Combines action types and instruments – the latter grouped under 'demand-side innovation' instruments.

Classifiers at participant / applicant level

Classifier code	Description
DIT_STAKEH_CAT_FINAL	Research, Industry, Public admin, Assoc_NGO_foundations
DIT_ORG_TYPE_FINAL	HES, REC, PRC_LE, PRC_SME, PUB, OTH
EC_NACE2_Level1/2/3_CODES & Labels	Nace codes & labels at 3 levels, based on ORBIS data provided by the EC (core codes). Available only for the LEIT participants.
DIT_CountryGroup_H2020	EU15, EU13, H2020 AC, Third Country.
DIT_GEO	EFTA, EU MS, EU MS UK, Other EU AC, EU Other, INTL_BRIC, INTL_High-Income, Intl_Other

A2 Frameworks structuring the analyses related to concept of transitions

Taxonomy of failures justifying R&I policy interventions

	Type of failure	Failure mechanism
Market failures	Information asymmetries	Uncertainty about outcomes and short time horizon of private investors lead to undersupply of funding for R&D.
	Knowledge spill-over	Public good character of knowledge and leakage of knowledge leas to socially sub-optimal investment in (basic) research and development.
	Externalisation of costs	The possibility to externalise costs leads to innovations that can damage the environment or other social agents.
	Over-exploitation of commons	Public resources are over-used in the absence of institutional rules that limit their exploitation (tragedy of the commons).
Structural system failures	Infrastructure failure	Lack of physical and knowledge infrastructures due to large-scale, long-time horizon of operation and ultimately too low return on investment for private investors.
	Institutional failures	Absence, underperformance, or excess of 'hard' institutions (organisations) or 'soft' institutions (laws, standards, traditions, etc.).
	Interaction or network failure	Strong or weak network failure: that is, overly tight network connections causing lock-in or too-loose connections, leading to a loss of communication, cooperation and opportunities.
	Capabilities failure	Lack of appropriate competencies and resources at actor and firm level prevent the access to new knowledge, and lead to an inability to adapt to changing circumstances, to open us novel opportunities, and to switch from an old to a new technological trajectory.
Transform-ational system failure	Directionality failure	Lack of shared vision regarding the goal and direction of the transformation process: inability of collective coordination of distributed agents involved in shaping systemic change; lack of targeted funding for research, development and demonstration projects and infrastructures to establish corridors of acceptable development paths.
	Demand articulation failure	Insufficient spaces for anticipating and learning about user needs to enable the uptake of innovations by users. Absence of orienting and stimulating signals from public demand. Lack of demand-articulating competencies.
	Policy coordination failure	Lack of multi-level policy coordination across different systemic levels, or technological and sectoral systems; lack of horizontal coordination between research technology and innovation policies and sectoral policies; lack of vertical coordination between ministries and implementing agencies; no coherence between public policies and private sector institutions; no temporal coordination resulting in mismatches related to the timing of interventions by different actors.
	Reflexivity failure	Insufficient ability of the system to monitor, anticipate and involve actors in processes of self-governance; lack of distributed reflexive arrangements to connect different discursive spheres, provide spaces for experimentation and learning; no adaptive policy portfolios to keep options open and deal with uncertainty.

Source: Arnold, E. et al (2018), Technopolis Group, modified from (Weber & Rohracher, 2012)

Avenues for transformative innovation policy

Avenue	Policy message
Emergence of radical innovations	Support a wide range of sustainability innovations, not just technological but also social, infrastructural and business model innovations.
	Support more real-world experiments, pilots, demonstration projects and living labs, which move innovations beyond the R&D phase and enable open-ended learning with multiple stakeholders about technical performance, market uptake, social acceptance and environmental impacts.
	Build transformative innovation coalitions which not only include 'traditional' actors (universities, research centres, firms), but also new entrants (NGOs, cities, startups, pioneers) that are willing to challenge conventional wisdom and to think 'out of the box'.
	Nurture new market creation (e.g. through subsidies, public procurement, feed-in tariffs) and new business models so that radical innovations can become economically viable.
Diffusion	Insights and findings from local projects and experiments should be shared, compared, aggregated, codified, and disseminated, which could be done by intermediary actors such as innovation or implementation agencies.
	Research, development, and innovation policy can help improve price/performance characteristics of innovations, which stimulate diffusion.
	Adoption by consumers can be stimulated with targeted financial instruments (purchase subsidies, low-interest loans, tax exemptions), information provision (media campaigns, labels, celebrity endorsements) and adjustments in economic framework conditions.
	Uptake of innovations in businesses can be supported with financial instruments that reduce investment risks (e.g. interest-free loans, capital grants, investment subsidies), regulations (e.g. renewable energy obligations for utilities, electric-vehicle sales targets for automakers, environmental standards for home builders), and public infrastructure investment.
	Policymakers can support the social acceptance of innovations by developing positive visions and debates and by involving societal groups through public participation.
Disruption and system reconfiguration	Reconfiguring entire systems should go beyond technological 'silver bullets' and promote synergies among multiple innovations.
	Since transitions are full of surprises, non-linearities and unintended consequences, adaptive governance approaches are recommended, based on iterative cycles of policymaking and planning, implementing, evaluating and learning.
	To mitigate potential resistance from incumbent firms, policymakers could assist them in strategic reorientation processes or provide compensation (e.g. sunset clauses).
Cross-cutting policy recommendations	Horizontal coordination between policy domains (innovation, transport, energy, industry, education, skills) is important, especially in the later phases.
	Meeting the large investment needs for diffusion and infrastructure change will require policies that change market incentives, reduce risks and uncertainties, and incentivise private investment, as well as more fundamental reforms of the financial system.
	Long-term change and directing innovative trajectories towards grand challenges should be promoted through ambitious visions, missions and targets.

Source: EC (2020) Science, Research and Innovation performance of the EU2020 – Transformative innovation and socio-technical transitions to address Grand Challenges, Chapter 9, DG Research and Innovation

APPENDIX B: STRUCTURED OVERVIEW OF EVALUATION QUESTIONS

The table below provides the lists of evaluation questions and the report section where they are addressed. Text written in red indicates the topics for investigation, in some cases they are covered in different report sections.

This table lists only the evaluation questions that were expected to be covered in this evaluation. Questions highlighted in green were expected to be covered based on the back-to-back studies.

		EVALUATION CRITERIA / QUESTIONS	Report section
RELEVANCE	1	How relevant has the Framework Programme been in this area given the stakeholders' needs and considering the scientific, technological and/or socio-economic problems and issues identified at the time of its design and over time?	4.1
	2	To what extent have the supported thematic areas taken into account the latest technological, scientific and/or socio-economic developments at the national, European and international level? What are the emerging needs in this area that the Framework Programme has not covered?	4.1
	3	Has the Framework Programme tackled the right issues given the positioning of the European Union in this area since the programme started and over time?	4.2
	4	To what extent has the Framework Programme in this area addressed the needs of groups targeted for application/participation in terms of tools and thematic areas covered? Are the activities as they exist today appropriate to address the needs? What is missing?	4.1
	5	To what extent have the Framework Programme activities to support the Digital and Industrial Transition demonstrated to be flexible to cope with changing circumstances in Europe and in the world?	4.1
	6	In which areas is the participation of international partners and Associated Countries the most relevant to support the Digital and Industrial Transition? How does this participation fit into the objectives of the Framework Programme, including to reinforce Europe's relative positioning in this area?	4.2
	7	To what extent have the objectives of the partnerships been, and are still relevant regarding the challenges and needs addressed in this area by the Framework Programme?	4.3

		EVALUATION CRITERIA / QUESTIONS	Report section
EFFICIENCY	1	How efficient have the implementation processes of the Framework Programme under the programme parts specifically covered in this procurement been in terms of administration and management, in terms of project application and selection processes, in terms of funding allocation, in terms of forms of implementation (e.g. partnerships, collaborative research, blending; bottom-up/top-down actions)? How did these processes cater for flexibility needs in implementation? What have been the barriers or drivers? How could they be addressed or what else could be done to maximise the benefits of the Framework Programme implementation under the programme parts specifically covered in this procurement? To what extent have the programme implementation processes in this area influenced the types of projects selected? What can be learned in terms of implementation processes from the experience of applicants and participants under the programme parts specifically covered in this procurement? What were the key barriers and drivers towards progress they have experienced at application stage and during the implementation of the projects, and their consequences for the researchers and organisations involved? To what extent are project application, management, and reporting being performed by organisations other than those performing the research and innovation activities under the programme parts specifically covered in this procurement? What are the underlying reasons and implications (e.g. in terms of costs, quality of applications, R&I activities) for the beneficiaries and for the Commission?	5.1.1 5.1.2 5.1.3 5.1.4
	2	To what extent has the Framework Programme under the programme parts specifically covered in this procurement been cost-effective? How proportionate were the costs of application and participation borne by different stakeholders groups, taking into account the associated benefits under the programme parts specifically covered in this procurement? Are the administrative costs borne by applicants and participants lower, higher or constant if compared with the previous Framework Programme? Please quantify them to the extent possible. How to lower costs of applications and increase benefits from participation for the applicants (i.e. cost of writing proposals) and Commission services (i.e. cost of administrating and running the programme) under the programme parts specifically covered in this procurement?	Section 5.2.1 5.1.2
	3	To what extent have the Framework Programme monitoring and evaluation systems and feedback to policy processes been efficient to ensure evidence-based policy making in this area? Were adequate systems put in place to share lessons learnt from implementation and results achieved between Framework Programme interventions in this area? To what extent does the programme communication/valorisation strategy allow identifying, capitalising upon and (possibly) transferring good practices/results?	Section 5.1.5
	4	How cost-effective have the partnerships under focus been?	5.2.2

		EVALUATION CRITERIA / QUESTIONS	Report section
EFFECTIVENESS	1	What are the main results and (expected) outcomes and scientific, economic and societal impacts from the projects supported under the programme parts specifically covered in this procurement? Is the delivery of the projects' results all together leading to the achievement of the programme's objective(s) in this area? What is needed to be able to reach the objectives and by which timeframe? What internal or external factors have influenced progress or lack of progress of the Framework Programme interventions to contribute to the Digital and Industrial Transition? Are there any factors that are more or less effective than others, and, if so what lessons can be drawn from this? What could be done to address barriers in the short and longer term? What are determinants for success/failure in advancing the state of the art and/or the maturity of technologies? What could be done to address barriers in the short and longer term? To what extent have dissemination, exploitation and communication measures enabled to reach these outcomes and impacts? What further actions are needed to maximise the impact of the Framework Programme interventions to contribute to the Digital and Industrial Transition?	6.2.1 6.2.2 6.2.3 6.3.1 6.3.2, 6.3.3 6.3.2
	2	To what extent has the Framework Programme under the programme parts specifically covered in this procurement contributed to achieving the European Union policy priorities and the Sustainable Development Goals (SDGs)?	6.2.3
	3	To what extent has international cooperation and, more specifically, association of third countries to the EU Framework Programme made a difference in achieving the objectives of the Framework Programme in this area? How does international participation fit into the objectives of the Framework Programme, including to reinforce Europe's relative positioning in this area? Has international cooperation, and specifically association, increased the impact for the EU in this area? (To be measured by category of Associated Countries and by Framework Programme part in order to fully assess its impact and inform future policy choices.)	6.3.2
	4	To what extent did the Framework Programme under the programme parts specifically covered in this procurement advance the state of the art and the maturity of technologies? To what extent are the results exploited? To what extent did the Framework Programme under the programme parts specifically covered in this procurement advance the maturity of technologies, inter alia, in terms of the Technology Readiness Levels and in terms of innovative products and services based on the results of the projects, during and after the projects? To what extent are the results exploited? Are there any Important differences in accelerating innovations compared to previous framework programmes?	6.2.1 6.2.2 6.3.2
	5	To what extent have the partnerships achieved their objectives and the objectives of the Framework Programme in this area?	6.2.5 & 6.3.4
	6	To what extent do the activities and outputs of the funded actions (projects, partnerships and other) contribute to making European industry more sustainable (greener), resilient and human-centric?	6.2.3 & 6.3.3
	7	Has the programme led to results, such as technological developments and collaborations, that have a dual use? Are there cases where unethical or against human rights activities have materialised during or after the project duration? How effective has the ethics evaluation of proposals and ethics follow-up of projects been? What could be done to prevent, identify and/or manage such risks?	Section 6.2.3
	8	To which extent did projects propose tangible improvements and reforms of skills in work force and curricula for educational establishment/universities?	6.3.1

		EVALUATION CRITERIA / QUESTIONS	Report section
	9	To what extent have bottom-up schemes with open calls (ERC, FET-Open, MSCA, EIC- Pathfinder, etc.) contributed to the identification and early leadership in new and emerging enabling technologies?	6.2.1
	10	To what extent do the activities and outputs of the funded actions (projects, partnerships and other) contribute to making European industry more sustainable (greener), resilient and human-centric?	Section 6.2.3

		EVALUATION CRITERIA / QUESTIONS	Report section
COHERENCE	1	How coherent has the Framework Programme been in this area, between Framework Programme parts covered by this study and with other parts of the Framework Programme not covered by this study (e.g.other clusters, excellent science, etc.)?	Section 7.1.1
	2	How is the level of coherence among partnerships, and between partnerships and the Framework Programme activities in this area? Are partnerships more effective in achieving synergies to deliver on the Digital and Industrial Transition, compared to other modalities of the programme?	Section 7.1.2
	3	How coherent has the Framework Programme been in this area > with other EU programmes serving similar objectives (e.g the EU Space Programmes EGNSS and Copernicus, Destination Earth, etc.) and with relevant national, regional or international initiatives? What is the positioning of the Framework Programme in this area within the overall European research and innovation landscape (incl. R&I funds at national, regional and European level) and beyond (at international level)?	Section 7.2.1, 7.2.2, 7.2.3
EU ADDED VALUE	1	What would have happened if the Framework Programme had not existed? Could the stakeholders have implemented the related research and innovation activities in another way, including through other national or regional support?	Section 8.1
	2	What is the value resulting from partnerships in contributing to the Digital and Industrial Transition that is additional to the value that could result from interventions carried out at regional or national level?	Section 8.2
	3	What is the EU added value of the Framework Programme activities to support the Digital and Industrial Transition?	8.3

		EVALUATION CRITERIA / QUESTIONS	Report section
PARTNERSHIPS	1	How much private and/or public R&I contributions has been mobilised on EU priorities thanks to partnerships? What is the partnerships' budget leverage factor, in mobilising additional resources, on top of contribution from partners?	Section 5.2.2
	2	How do Partnerships facilitate the creation and expansion of R&I networks that bring together relevant and competent actors from across Europe, thus contributing to the realisation of the ERA?	Section 6.2.1
	3	How open are partnerships to new participants? Are there procedures / mechanisms in place to expand the partnership to involve new members at partnership and project level, as well as gradually engage a broader set of stakeholders across Europe? What is the level of openness in use of research result? To what extent are partnerships (notably with industry participation) accessible for SMEs?	Section 6.2.1

APPENDIX C: MAIN CONCLUSIONS AND RECOMMENDATIONS AT LEIT PROGRAMME LEVEL

C1 LEIT ICT

LEIT ICT contributed to the Digital and Industrial Transition by upgrading Europe's scientific and technological capacity and contributing to structural changes. The present section provides our conclusions regarding the achievements and shortcomings of LEIT ICT in delivering results and contributing to the Digital and Industrial Transition, together with recommendations.

LEIT ICT's focus on the selected intervention areas responded to the technological trends and socio-economic developments and was well **aligned with the stakeholders' needs**. The priorities, their focus, and the selection of the funding instruments addressed existing market, systemic and transformational failures by reducing risk and entry barriers, especially for SMEs, pooling resources to address capacity and capability failures and building ecosystems around value chains. To further improve the alignment with stakeholders' needs the following areas need to be addressed:

- There are strong interlinkages among the technologies, and very often technologies from different intervention areas are part of the same value chain. In the absence of a coordination mechanism, such interlinkages were addressed ad-hoc and bottom-up. The European Commission's decision to adopt a portfolio management approach at the LEIT ICT level, with active coordination between the various intervention areas and between relevant cPPPs and JUs and the mainstream FP, will better exploit complementarities.

- The increasing speed of technological change can challenge the relevance of the defined priorities. Although the update of the priorities and the time to grant has been significantly improved compared to FP7 the reflexivity of the Programme could be further improved by considering, as a complementary source, inputs from the industry during the design of the mainstream FP work programme, especially from SMEs working on emerging fields.

The Programme's design and its mix of funding streams and instruments is balanced and **contributed to the generation of the expected scientific and technological outcomes**. The funding sources were effective in taking up breakthrough research and research on emerging technologies from FP7 and bottom-up schemes of H2020. Partnerships encouraged multidisciplinary research through their SRIAs and stakeholders from various sectors and technologies across the value chains were involved. Multilevel coordination – EU-National and among the Member States – was achieved by partnerships that increased the synergies and improved policy coherence. In addition to the positive elements of the design, some drawbacks hinder effectiveness:

- The allocation of funding between medium TRL (RIAs) and high TRL (IAs) shifted gradually for the benefit of hight TRLs. The share of RIAs in the total budget was reduced from 61% in the WP 2014-201 to 51% in the WP 2018-2020. At the same time the share of IAs was increased from 30% to 46%. Despite the ability of taking up low TRL research from FP7 and the bottom-up schemes of H2020, reduction of the medium level TRL supported by RIAs might prevented the full exploitation of opportunities to take up low TRL research.

- The overall budget available for the mainstream FP and the cPPPs was insufficient to address the funding needs and expectations of the R&I community. Increasing the budget across all intervention areas for the mainstream FP and the cPPPs will allow the exploitation of the opportunities offered by high-quality proposals that otherwise will be abandoned

- The case studies found that simple and flexible instruments such as FSTPs can deliver positive direct, indirect and spillover effects, as they can lower the entry barriers and allow the engagement of new actors, especially SMEs or participants from EU13. Nevertheless, the current monitoring system at the level of the FP does not record any information about the profile, activity, and outputs of the beneficiary companies, resulting in a significant information gap that prevents the assessment of their contribution to the objectives of the Programme. Even more, the current information overestimates the role of the participant types which in several cases are mainly administering the cascading funding.

Although there is a tendency to concentrate the funding on big projects, as the average project budget increased from €2.5-3m until 2017 to €6.5-7.5m in 2018-2020, this was mainly an effect of the launching of 'demand-side' instruments, such as the platforms and hubs, pilot lines, testbeds, and public procurement projects. These instruments, by design, involved a large number of beneficiaries including SMEs (e.g. in the case of cascading funding) end the risk of raising barriers to entry is low. The geographical concentration is of a higher concern as the 15 Widening Member States attracted 14% of the funding, while the EU12 absorbed 71%. Therefore, more efforts are necessary to increase the participation of from the Widening group.

LEIT ICT reached a transformational effect by directing research and industry efforts into **sustainability issues and societal challenges**. The Programme made progress towards adopting a more human-centric approach. Behavioural changes were also reported in Research Organisations and industry as survey respondents indicated long-lasting effects in their research and innovation agendas towards the above dimensions. The priority-setting procedures followed by the EC and the partnerships, taking a strong consensus-based approach through the involvement of a broad spectrum of stakeholders and, specifically in the Partnerships, the development of common SRIAs, were a critical enabling factor in this context. In addition to the enablers, there are also hindering factors that need to be addressed:

- Market forces tend to concentrate resources in areas of strength, where competitive advantages could be built. Therefore, bottom-up approaches in priority setting are often ineffective in directing resources towards structural industry weaknesses. Consequently, in addressing weaknesses of Europe, some directionality is necessary to be infused in the instruments targeting those critical areas.

- Enhancing interdisciplinarity and diversity of participants could strengthen transformational effects.

International collaboration with Third Countries was limited and mainly implemented by CSAs aiming at achieving a level of coordination for the development of standards, ensuring the interoperability of technologies, adoption of common positions and synchronisation of strategies and few research projects with relatively small sizes. Progress was often hindered by the lack of coordination at the policy level and the broader geopolitical changes after 2017, which raised concerns regarding Europe's technological and data sovereignty. Research collaboration projects were much fewer, with relatively small size and low impact. Similarly, **standardisation** remained insufficient due to several factors, including the limited interest of industry and long processes that exceed project life that hinder the synchronisation of research with the standardisation process. Under LEIT ICT, a mixture of CSAs and collaborative research projects encouraging pre-standardisation activities were contracted. To address the hindering factors, the following are proposed:

- Efforts to achieve digital sovereignty in Europe should not hinder international collaboration, although a technology and country specific approach within a broader political framing is needed to achieve trust and reciprocity in global collaborations, especially at higher levels of TRL.

- Given the sensitivity of the standards and their impact on the competitiveness and global positioning of the European industry, a stronger multi-level coordination effort is needed involving the relevant standardisation bodies and international partners. Pre-standardisation research activities will remain essential and need to be further supported with funding and setting specific project requirements. SRAs could play a significant role in the coordination of international collaboration and standardisation and provide the long-term vision that is necessary for the synchronisation with the standardisation process.

C2 LEIT NMBP

LEIT NMBP contributed to the Digital and Industrial Transition by upgrading Europe's scientific and technological capacity and contributing to necessary structural changes. The present section provides our conclusions regarding the achievements and shortcomings of LEIT NMBP in delivering results and contributing to the Digital and Industrial Transition, together with recommendations.

LEIT NMBP's focus on the selected intervention areas responded to the technological trends and socioeconomic developments and was aligned with the stakeholders' needs in general. The priorities, their focus, and the selection of the funding instruments addressed existing market, systemic and transformational failures by reducing risk and entry barriers pooling resources to address capacity and

capability failures and building ecosystems around value chains. To further improve the alignment with **stakeholders' needs** the following areas need to be addressed:

- Ensure a good **balance between all stakeholders** and make sure the different stakeholders can benefit from their respective roles: knowledge from HES, RTOs to integrate and bridge to industry, SME to be well represented and need for industrial leadership in funded projects.

- Integrate more **manufacturing companies** in FP projects, particularly industrial technology end-users and SMEs; including the broadening of the participating industrial sectors (with focus on manufacturing SMEs across different sectors and especially in the process industries area SME technology providers).

- Keep or re-activate project formats and call **requirements that are attractive for SMEs** (the SME ratio in NMBP is better than in other programmes but should be maintained; SMEs often need translation and guidance).

- Develop a clear strategy and portfolio of measures to **integrate more participants from the EU13** (EU13 has 5% funding compared to EU15 88%). Utilise existing transfer mechanisms/potential and support with dedicated resources (e.g. via hop-on facilities and the possibility to be a subcontractor with less risk and efforts needed; also smaller projects with less partners and budget, but more focused tasks and less expected output/outcome).

The Programme's design and its mix of **funding streams and instruments** contributed to the generation of the expected scientific and technological outcomes and results. The funding sources were effective in taking up breakthrough research and research on emerging technologies. Partnerships (e.g. ERA-NETs and CPPPs) encouraged multidisciplinary research and stakeholders from various sectors and technologies across the value chains were involved. Multilevel coordination – EU-national and among the Member States – was achieved by partnerships that increase the synergies and improve policy coherence. To improve the effectiveness of the Programme the following action points are recommended:

- Keep the **balance between instruments** (RIA vs. IA) with their functions along the innovation chain, ultimately generating impact; and better align the functionalities of the instruments with the stakeholders, topics addressed, and TRL levels as well as objectives. Make use of CSAs to go beyond the scope of individual projects.

- Do **not lose lower/medium TRL** funded research (and HES and LEs in RIAs). Also, give more flexibility in changing objectives during projects (especially at comparably lower TRL level where a shift in scope might be needed).

- Foster and strengthen **seamless funding** towards deployment and large-scale investments along the whole industrial innovation value chain. Make sure the different instruments are aligned "seamlessly" along the innovation value chain (e.g. from RIA to IA with a target to focus on TRL 5-7 and to describe the route towards FOAK/TRL9). The Framework Programme cannot fund FOAK installations, but a promising success at a high TRL in the Framework Programme should be a door opener to also be funded e.g. through the EU Innovation Fund, the IPCEI programme, the European Investment Bank and/or regional/national funds. Funding bodies should cooperate in this respect and could also invite high potential projects to apply for the deployment of promising innovations.

- At least, keep the **balance of funding over the seven-year period**, with more funding focus on the start of the FP programme period (in H2020 it was the other way round: absolute funding and average funding per project increased over time). This is relevant especially for time critical tasks and projects, particular in process industries.

- Question the size and composition as well as **outcomes of Open Innovation Testbeds (OITB), hubs etc**. A broader number of SMEs should benefit from those infrastructures. It is needed to analyse the real industry needs. Also, a larger budget might be needed in the implementation phase but will not continuously be needed.

- Give topics with critical mass a chance to be continued. Make use of existing possibilities, e.g. through programme lines or ERA-NET type structures.

- Make sure the **value chain** is represented (around use cases/applications) in a way that projects do not become too big (larger projects do not mean more participants, check coverage of value chain) or they become ineffective.

- **Increase the success rates** (NMBP 8%). Be flexible to allocate more budget for areas where there is a high oversubscription. The success rate is regarded as a real challenge to increase industrial participation, especially for SMEs. It is needed to make it cheaper and less time-consuming to prepare a proposal: two-stage proposals can be part of the solution.

The **priority-setting procedures** followed by the EC and the partnerships, taking a strong consensus-based approach through the involvement of a broad spectrum of stakeholders and, specifically in the Partnerships, the development of common SRIAs, were a critical enabling factor in this context. In addition to the enablers, there are also hindering factors that need to be addressed in order to optimise priority-setting procedures:

- Ensure a clear, transparent and well-coordinated process for **translating the SRIAs** into concrete and convertible call texts (with delivery dates). The more clearly the calls for proposals are aligned with the needs defined in the SRIAs, the higher the effectiveness and quality of the proposals will be.

- Agree on a clear **timeline and budget for funding** between EC and private side of the cPPPs over the whole period of the FP.

- Organise **strategic structures and mechanisms** (e.g. alignment through strategies and roadmaps to avoid too much overlap) for stakeholders to exchange across clusters and partnerships (DGs, associations, partnerships, etc.) and try to prevent internal competition (e.g. across EC services). Do not lose the variety of R&D topics, but cluster them through exchange. Make clear at the same time who is in charge of coordinating which form of collaboration dedicated to a specific task.

In order to **improve dissemination** and outcomes of projects, funding lines and the programme:

- Enable more **professional dissemination** in projects like RIA, IA (which has to be in the hands of the content owner/ experts in the topics). Dissemination via CSAs (e.g. to support community building) is relevant rather when a critical mass of topics/ activities is achieved or upcoming topics need to be further explored and aligned.

- Increase **project follow-up transfer mechanisms** and give dedicated time and resources for transfer already towards at the end of the projects (less deliverables, but more transfer and formats for it), e.g. via impact workshops.

- Avoid creating new structures/platforms that cannot be sustained at the end of projects, especially when replicating what already exists. Rather, engage a **better use of already existing platforms**/ conferences for exchange of research results in case of topics with critical mass.

- Enable and ask for **targeted cross-project exchange** (from the same call, with same/similar objectives, between relevant connected funding lines). Assign project tasks for it.

- **Reduce complexity in (systemic) projects** and foster (cross-sectoral) transfer of solutions and applications.

To improve **internationalisation** and at the same time alignment of stakeholder needs and funding instruments, the partnerships often have a special and critical function. The following action points for improvement are recommended:

- There are **specific functions of the several partnership formats** (e.g. PPPs, ERA-NETs, EITs) which should be used to further develop towards complementarity and targeted transfer between the different formats, governance levels and within European regions.

- European **Partnership SRIAs can serve as "blueprints" for national and regional complementary** funding programmes and results from European projects can be used and further developed/adapted in the national/regional context (particular via associations and its members, cluster/project coordinators, MS delegates and NCP, EIT KICs). Also, national representatives

should be well informed about the partnership process leading from the SRIA of cPPPs to the call topics of the FP, e.g. via mirror-groups being part of the partnership governance structure.

- **Defragment ERA-nets** (which are still very relevant) and support particularly their bridging function between the different levels of governance, between different types of stakeholders and regions/countries in Europe (particularly via agencies). ERA-NETs are suitable for cross-EU community building but regarded to be more effective if follow-up / connected activities and critical mass in topics is realised (e.g. interconnected successors and no singular activities). The M.ERA-NET is regarded as positive example with a meanwhile third funding period (M.ERA-NETs 1 to 3). Thus, further develop ERA-NETs as a complementary scheme to connect to MS in particular topics/areas, to integrate (local/regional oriented) SMEs that do not participate in FP calls, to improve connection and pooling between EU/EC and national/MS/regional funding, and to support understanding and cooperation between regions and MS.

- Foster **international cooperation particularly in (horizontal) and lower TRL topics** not (yet) at the core of competitive advantages (NMBP H2020 collaborative projects only had a 2% share of international participation). To identify topics for cooperation, differentiate where the EU and where third countries can benefit from complementary added value (e.g. third country partners are frontrunners and European companies could benefit from the information exchange). Agreements for funding on both sides need to be prepared going beyond statements that projects should include international partners, if cooperation should work successfully.

C3 LEIT Space

Draft conclusions and suggestions for improvement are provided in relation to LEIT Space and in relation to LEIT Space's contribution to Digital and Industrial Transition.

In relation to the LEIT programme performance

LEIT Space was designed to build on the achievements of FP7 with regards to Galileo and Copernicus, and which focused on the development of critical space infrastructure. LEIT Space had three general objectives which were: 1. The creation of an innovative EU space research community; 2. A cost-effective, competitive, non-dependent and innovative EU space industry; and 3. Space infrastructure to meet current and future societal needs.

It was therefore designed to better support existing and promising areas of industrial competitiveness, while also supporting socio-economic objectives in the EU generally.

There is a consensus that the intervention areas of LEIT Space were appropriate and that the Commission consulted widely in advance of finalising the LEIT Space Work Programmes. From industry's perspective, a number of weaknesses can nevertheless be identified in terms of quicker commissioning of Calls for Proposals/projects relating to satellite navigation and other core competences of the EU space sector.

Still, both national and industry stakeholders recognised the difficulty in the prioritisation of funding/topics and the importance of covering the complete space value chain – not just upstream space. It is recognised that priorities and funding should be demand-driven, starting from the perspectives of the users and the idea of applications.

LEIT Space was well aligned with stakeholder needs and the Work Programmes were effective in identifying and addressing relevant failures. For example, the WG 2018-2020 indicates that real-world industrial/commercial requirements, or societal needs, shall drive the Innovation Actions so that the projects' results can find their logical path towards market adoption.[132]

Overall LEIT Space 2020 was considered to be more effective in addressing stakeholder needs and market failures compared to FP6 and FP7.

In this sense, there is also a consensus that LEIT Space is outperforming the current Horizon Europe programme in terms of relevance, effectiveness, and efficiency.

[132] European Commission (2018) Horizon 2020 Work Programme 2018-2020 5.iii. Leadership in Enabling and Industrial Technologies – Space.

Suggestions for improvement

- The LEIT Space programme was well-received overall by stakeholders and was also positively evaluated at the mid-term stage. The overall conclusion of this study is that the programme was both relevant and mostly effective. The overall conclusions for other evaluation criteria are also predominantly positive albeit with some weaknesses. LEIT Space is not only considered an improvement compared to its predecessor FP7; there is also a consensus among stakeholders that many of the characteristics of LEIT Space would also benefit the current Horizon Europe structure and implementation. Some of the conclusions, including the enabling factors identified, could therefore be (re-)introduced into the latter half of Horizon Europe.

- Overall, the Work Programmes and commissioning of Calls for Proposals were well received under LEIT Space. However, some weaknesses were identified in the timing of calls relating to Satellite Navigation. Given the high European competitiveness in this area, there may be the opportunity to draw on lessons learned to improve the timing of calls covering such central topics.

- With regards to SpaceTechSc, it may be beneficial to consult and evaluate the possibility of creating separate funds for science and for space technology to ensure that neither area is usurped by the other. This could be done by taking into account how other low TRL funding in H2020/Horizon Europe – and at national level – contribute towards space R&D at higher TRL levels.

- LEIT Space made progress in the involvement of end users in the design of applications and in the implementation of projects. However, the involvement of (a wide range of) end users could benefit from continued support given i) the diversity of public and private end users, ii) their limited familiarity with the space sector and its potential in other socioeconomic areas. Support may be stipulated through the calls for proposals or through other means.

- In addition to the continued support for end-users, other smaller/peripheral actors that have relevant competencies/interest in space projects, including using data derived from space, also call for further support, including through simplified eligibility criteria.

- LEIT Space faced some challenges in identifying and/or allocating suitable evaluation experts to assess SME Instrument proposals submitted under Space Innovation. Some lessons may be learned from this including gaining a better understanding of the needs/challenges of SMEs operating in the space sector.

- Many stakeholders emphasised the great challenges tackled under the PROTEC intervention area and the need for more funding for space in general and for PROTEC in particular. One proposed solution to this may be to establish an ERA-NET Cofund which would, in line with other ERA-NETs, fund selected space topics relevant to a group of Member States.

In relation to the contribution to Digital and Industrial Transition

During the design and implementation of LEIT Space, the EU has had to react to major geopolitical events. The Union has also extensively debated and revised its socioeconomic priorities, reacting to the realisation of climate change and mitigation needs.

The general developments of the global geopolitical situation, the COVID pandemic – and later the war in Ukraine – has given Europe a drastic new strategic and geopolitical dimension with regards to security and non-dependence. Although some of these events have occurred in parallel with the implementation of LEIT Space, the objectives of economic resilience, strategic autonomy, and geopolitical power were present in the LEIT Space programme design, too.

In the last decades, space policies and their applications have gained in political relevance due to their capacity to tackle global challenges, such as the climate and biodiversity crises, but also due to the growing reliance of the EU economy and society on space infrastructure, services, and data.

With regards to the role of LEIT Space, green and digital transition topics have been directly and indirectly supported by the programme. In particular, new EO technology and satellite communications fit into these objectives. Autonomy and resilience are critical aspects of space components development. However, their value toward green and digital transition are not consistently understood by wider society.

For instance, by lowering aviation emissions and improving land- and sea-based routes, Galileo and EGNOS contribute towards the adoption of sustainable transport modes. Also, EGNSS and Copernicus can both help to innovative and sustainable farming practices.

Suggestions for improvement:

- LEIT Space has made important contributions to the development of downstream services and applications that can be used to (inter alia) monitor the effects of and mitigate climate change. Data-driven applications also have great potential to (continue) to support the attainment of SDGs, and EU Green Deal (transition) policies in the areas of (inter alia) agriculture, transport and energy. Therefore, further recognition and efforts to continue support in this area will be needed. This would include funding, actively encouraging the cooperation of the end users and so on.

- The potential of space applications for wider societal benefit is vast. However, it also entails the involvement of R&I performers outside the core specialisations of space. Their capacities to become (more) actively engaged and to invest their time and resources require support. Support mechanisms could for example include:

  - Consultations with key non-space actors to better understand their needs and challenges

  - Awareness campaigns promoting the wider opportunities of space through for example match making events directly targeted at core space actors and public and private non-space actors alike

  - Key conclusions of a and b could be incorporated into future FP work programmes

- The cooperation between ESA and the Commission (as well as EUSPA and JRC) is an important driver for space R&I. To incorporate a digital and green transition element more directly, it may be beneficial to ‘open up’ this collaboration to key EU stakeholders with particular green and digital expertise.

- One conclusion of this study is that LEIT Space missed opportunities related to the funding of small-scale solar cells in space. The EU RTD Framework Programmes could therefore learn from this omission and (more) actively support green energy for space.

- Given the opportunities that space R&I have to provide Member States services and applications that can support their decision-making process, it may be pertinent to further widen participation in the prograsmmes to ensure that data-driven applications will also benefit the EU27 as a Union.

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The purpose of the first phase in the ‘Evaluation Study on the European Framework Programmes for Research and Innovation for Addressing Global Challenges and Industrial Competitiveness – Focus on Activities for the Digital and Industrial Transition’ is to evaluate the contribution of the Horizon 2020 (H2020) Framework Programme to the Digital and Industrial Transition (DIT), supporting the European Commission’s ex-post evaluation. The evaluation considered all activities under the H2020 pillars and priorities. At the core was the H2020 ‘European leadership in enabling and industrial technologies’ (LEIT) programme part under the Industrial Leadership Priority. The scope included also the LEIT-related public-private and public-to-public partnerships and EIT KICs. The evaluation was conducted between January and November 2022, using a mix of qualitative and quantitative methods.

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